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4

Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure

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4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. *Short-term* refers to the period up to and during the completion of repository closure. For purposes of analysis, the duration that the repository would remain open varied between 50, 100, and 300 years after receipt of the first spent nuclear fuel or high-level radioactive waste shipment. Chapters 5 and 6 discuss the environmental consequences of long-term repository performance and transportation, respectively. Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of disposal containers and shipping casks, and a floodplain assessment. The implementation of the Proposed Action could require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

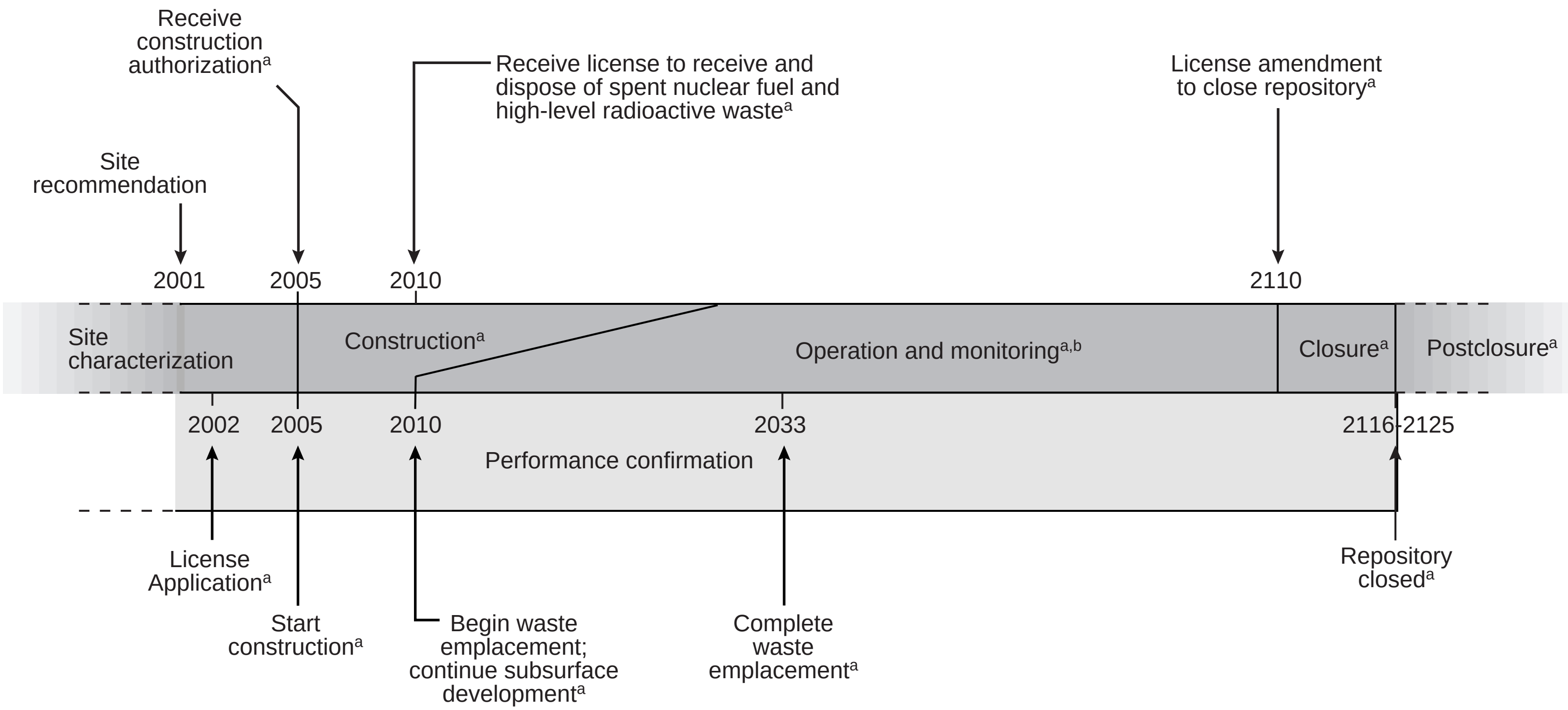
The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository. In addition, DOE analyzed packaging and thermal load scenarios to cover a reasonable range of possible impacts.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the analytic scenarios evaluated in this environmental impact statement (EIS). Chapter 2 describes these scenarios in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION PERFORMANCE CONFIRMATION ACTIVITIES (2001 TO 2005)

The performance confirmation program would continue the current site characterization activities—tests, experiments, and analyses—for as long as required. DOE would continue these activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to



a. If Yucca Mountain is approved.
b. The EIS analysis assumed that waste emplacement would occur over a 24-year period ending in 2033.

Source: Modified from TRW (1999b, Figure 1.5-1, page 1-3).

Figure 4-1. Expected monitored geologic repository milestones.

determine with reasonable assurance that the repository would meet the performance objective for the period after permanent closure.

INITIAL CONSTRUCTION ACTIVITIES (2005 TO 2010)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. Assuming this authorization, construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Initial subsurface construction would prepare the first emplacement drifts for the start of emplacement activities in 2010. As mentioned above, performance confirmation activities would be ongoing during this period.

CONTINUING CONSTRUCTION ACTIVITIES AND REPOSITORY OPERATION AND MONITORING (2010 TO 2110)

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. Assuming DOE received the license, emplacement of these materials in the repository would be likely to begin in 2010 and end in 2033. The development (construction) of the subsurface would continue during waste emplacement, and would end in about 2031 for the high or intermediate thermal load scenario or about 2032 for the low thermal load scenario.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary.

Monitoring activities would begin with the emplacement of the first waste package in 2010 and would last between 50 and 300 years. Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. To ensure flexibility for future decisionmakers, DOE is designing the repository with the capability for closure as early as 50 years after the start (26 years after the completion) of waste emplacement or as late as 300 years after the start (276 years after the completion) of emplacement. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for as long as 300 years after the start of emplacement. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement, but also assesses impacts for closure starting 50 and 300 years after the start of emplacement.

As mentioned above, DOE would continue its performance confirmation activities during the construction, waste emplacement, and monitoring activities.

CLOSURE PHASE (2110 TO 2116 OR 2125)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take from 6 to 15 years, depending on the thermal load scenario. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Potentially backfilling the main drifts, access ramps, ventilation shafts, and connecting openings

- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY ANALYTIC SCENARIOS

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a set of repository design scenarios (thermal loads) for evaluation in this EIS. Because it cannot predict the specific transportation option or mode (truck or rail) or the packaging option (canistered or uncanistered) for each shipment of spent nuclear fuel and high-level radioactive waste to the proposed repository, DOE has also identified a set of transportation and packaging scenarios for evaluation. Whether canistered or uncanistered, each shipment of spent nuclear fuel and high-level radioactive waste would be in a Nuclear Regulatory Commission-certified shipping cask.

DOE is considering three thermal load scenarios to represent the potential thermal loads that could be part of a license application to the Nuclear Regulatory Commission. These scenarios include a relatively high emplacement density of spent nuclear fuel and high-level radioactive waste (high thermal load), a relatively low emplacement density (low thermal load), and an emplacement density between the high and low thermal loads (intermediate thermal load). The emplacement density of spent nuclear fuel and high-level radioactive waste in the repository is referred to as the *areal mass loading* (the amount of material in a given area). The spacing of the emplacement drifts and the waste packages in those drifts would control the thermal load of the repository. The additional spacing required for lower thermal loads would increase the amount of subsurface area needed and, therefore, would require more excavation.

Because the specific mix of canistered and uncanistered spent nuclear fuel that would arrive at the repository is not known at this time, this EIS analyzes the following packaging scenarios to address the potential range of environmental impacts from surface facility operations:

- A mostly legal-weight truck, uncanistered commercial fuel receipt scenario (uncanistered scenario)
- A mostly rail, canistered commercial fuel receipt scenario (canistered scenario) that includes:
  - A disposable canister scenario
  - A dual-purpose canister scenario

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Performance Confirmation and from Land Withdrawal

Performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (4,900 acres), current right-of-way reservations N-47748 [210 square kilometers (52,000 acres)] and N-48602 [about 75 square kilometers (19,000 acres)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1).

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 3.5 square kilometers (870 acres) composed of small noncontiguous areas in the larger 600-square-kilometer (150,000-acre) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little between the thermal load and packaging scenarios. Most of the surface facilities and disturbed land would be in the North and South Portal Operations Areas. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would recontour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from performance confirmation, construction, operation and monitoring, and closure. Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling, nitrogen dioxide, sulfur dioxide, and particulate matter emissions from fossil fuel consumption, and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not consider the two other criteria pollutants, lead and ozone. There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a qualitative comparison to the new National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$). A Federal appeals court recently struck down the Environmental Protection Agency's new national ambient air quality standards for particulate matter (American Trucking v. EPA 1999, all). The Environmental Protection Agency has announced that it will appeal the decision. The EIS used these standards, among other air quality standards that were not at issue in that case, in analyzing the air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from NCRP (1996, Volume 1, pages 113 and 125) and ICRP (1994, page 24) to estimate doses to noninvolved workers (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases. Appendix G provides more details on the methods used for air quality analysis.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. Appendix G describes the methods, procedures, and basis of the analysis.

4.1.2.1 Impacts to Air Quality from Performance Confirmation (2001 to 2005)

Performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, nitrogen oxides, sulfur oxides, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen oxides, sulfur oxides, ozone). This analysis assumed that site characterization activities are representative of performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction (2005 to 2010)

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust (South Portal). The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the South Portal Operations Area
- Particulate matter from a concrete batch plant at the South Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all cases except one: the 24-hour PM_{10} concentrations for the three thermal load scenarios would be about 4 percent of the

Table 4-1. Estimated maximum construction phase concentrations of criteria pollutants and cristobalite at the analyzed land withdrawal area boundary (micrograms per cubic meter).[a]

			Thermal load					
			Maximum concentration[c]			Percent of regulatory limit		
Pollutant	Averaging time	Regulatory limit[b]	High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.36	0.36	0.39	0.36	0.36	0.39
Sulfur dioxide	Annual	80	0.088	0.088	0.091	0.11	0.11	0.12
	24-hour	365	1.0	1.0	1.0	0.28	0.28	0.29
	3-hour	1,300	6.3	6.3	6.5	0.49	0.49	0.50
Carbon monoxide	8-hour	10,000	3.8	3.8	4.1	0.037	0.037	0.040
	1-hour	40,000	23	23	25	0.058	0.058	0.062
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.66	0.70	0.65	1.3	1.4	1.3
	24-hour	150 (65)	6.1	6.4	6.0	4.0	4.3	4.0
Cristobalite	[Annual[d]]	[10[d]]	0.022	0.026	0.011	0.22	0.26	0.11

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be somewhat higher under the low thermal load scenario during the construction phase because of higher consumption of diesel fuel and resultant vehicle emissions around the South Portal Operations Area. The additional consumption and emissions would be related mainly to the preparation and maintenance of the excavated rock pile. Under this scenario, the rock pile would be about 5 kilometers (3 miles) east of the South Portal Operations Area, rather than in that operations area as it would be for the high and intermediate thermal load scenarios. Because the pile would be away from the South Portal Operations Area, it would not be subject to the operations area height restrictions. DOE could make a higher pile, reducing the area that would be disturbed and creating a more favorable surface-to-volume ratio for limiting fugitive dust emissions. This pile location would also be 5 kilometers farther from the location of the maximally exposed individual, which would result in lower PM_{10} concentrations. The PM_{10} contribution from surface disturbance activities would be about the same for the three thermal load scenarios. Overall, the slight differences in estimated concentrations do not provide meaningful distinctions between the scenarios.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996a, page 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles will rapidly deposit on the surface (EPA 1996a, page 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.025 microgram per cubic meter or less for the thermal load scenarios. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, from which it would be exhausted as part of repository ventilation. The analysis based potential releases of radon-222 on observed concentrations of the gas in the Exploratory Studies Facility during working hours when the ventilation system was operating. The concentrations ranged from 0.65 to 163 picocuries per liter, with a median concentration of 24 picocuries per liter. Total estimated radon releases of 1,500, 1,600, or 1,600 curies would occur during the construction phase for the high, intermediate, or low thermal load scenario, respectively. These releases, and the potential doses that resulted from them, would be similar because the excavated volume of the repository and the repository flowrate would be similar under each scenario. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be no more than 2.1, 2.5, or 2.5 millirem for the 5-year initial construction period under the high, intermediate, or low thermal load scenario, respectively. As a point of reference, the annual dose to the offsite maximally exposed individual would be about 5 percent of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit does not apply to releases of radon. The offsite population dose would be 11, 13, or 13 person-rem, respectively. The median dose to the maximally exposed noninvolved repository worker would range from 4.7 to 5.4 millirem annually during the initial construction period for the three thermal load scenarios. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all of the repository workers on the surface. Workers at the South Portal Operations Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air pathway would not exceed 10 person-rem for any thermal load scenario (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and initial construction period doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during initial construction period.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual	Total	Annual	Total	Annual
Dose to public						
Offsite MEI[c] (millirem)	2.1	0.43	2.5	0.49	2.5	0.49
80-kilometer population[d] (person-rem)	11	2.3	13	2.6	13	2.6
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	23	4.7	27	5.4	27	5.4
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)	9.0[f]	1.8[f]	10[f]	2.0[f]	10[f]	2.0[f]
Nevada Test Site noninvolved worker population[h] (person-rem)	0.012	0.0025	0.014	0.0028	0.014	0.0028

a. Numbers are rounded to two significant figures.
b. These releases were estimated using the average repository volume during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be 20 kilometers (12 miles) south of the repository.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Operations Area.
f. Values are for the uncanistered packaging scenario. The dual-purpose and disposable canister packaging scenario values would be somewhat lower, due to differences in the number of surface facility construction workers.
g. The analysis included noninvolved workers at both the North and South Portal Operations Areas.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Continuing Construction, and Operation and Monitoring (2010 to 2110)

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository, which would last from 2010 to 2110. Activities during this phase would include the continued excavation of subsurface drifts (2010 to 2033), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (2010 to 2033), the emplacement of disposal containers in the repository (2010 to 2033), and the continued monitoring of the disposal containers and maintenance of repository facilities (2034 to 2110).

4.1.2.3.1 *Nonradiological Impacts to Air Quality from Continuing Construction, and Operation and Monitoring*

DOE evaluated nonradiological air quality impacts from activities from 2010 to 2033, when handling and continued subsurface development and emplacement activities would occur simultaneously. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the placement and maintenance of excavated rock at a surface storage pile
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation
- Gaseous criteria pollutants and particulate matter from oil-fed boilers at the North and South Portal Operations Areas
- Particulate matter from a concrete batch plant at the South Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the thermal load and packaging scenarios. The lower thermal loads would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance. The uncanistered packaging scenario would require larger facilities at the North Portal Operations Area, which would necessitate a larger boiler for heating.

Table 4-3 lists estimated maximum concentrations at the analyzed land withdrawal area boundary for the high, intermediate, and low thermal load scenarios. These impacts are based on surface facilities built for the uncanistered packaging scenario. Other packaging scenarios would have similar or slightly smaller impacts because they would require smaller boilers.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For all three thermal load scenarios, the public maximally exposed individual would receive no more than 1 percent of the applicable regulatory limits, with one exception: the 24-hour PM_{10} value would be about 2 percent. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the analyzed land withdrawal area boundary. As discussed for the initial construction period (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The estimated exposures to cristobalite from repository operations would be small, about 0.015 microgram per cubic meter or less for all three thermal load scenarios.

Table 4-3. Estimated maximum criteria pollutant and cristobalite concentrations at the analyzed land withdrawal area boundary from emplacement, receipt and packaging, and development activities (2010 to 2033) during the operation and monitoring phase (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c]			Percent of regulatory limit		
			High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.45	0.45	0.82	0.46	0.46	0.83
Sulfur dioxide	Annual	80	0.14	0.14	0.16	0.18	0.18	0.23
	24-hour	365	1.8	1.8	2.1	0.50	0.50	0.57
	3-hour	1,300	11	11	13	0.87	0.87	1.0
Carbon monoxide	8-hour	10,000	4.2	4.2	7.3	0.041	0.041	0.072
	1-hour	40,000	28	28	46	0.070	0.070	0.11
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.22	0.22	0.27	0.43	0.44	0.54
	24-hour	150 (65)	3.0	3.1	3.4	2.0	2.1	2.3
Cristobalite	[Annual[d]]	[10[d]]	0.0097	0.012	0.015	0.097	0.12	0.15

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be somewhat higher during construction because of the higher rate of excavation. Concentrations of gaseous criteria pollutants would increase during emplacement and development activities because two boilers rather than one would be operating, even though vehicle emissions would decrease during emplacement and development. The exception would be emissions of carbon monoxide, which would be related more to vehicle emissions than boiler emissions. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions between the scenarios.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities (from 2034 to 2110) at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the analyzed land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

4.1.2.3.2 *Radiological Impacts to Air Quality from Continuing Construction, and Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase (2010 to 2033). Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities (2034 to 2110). During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Handling, Emplacement, and Continuing Development Activities (2010 to 2033). The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (NRC 1979, page 4-10). From 90 to 2,600 curies would be released annually, depending on the packaging scenario (TRW 1999a, page 75). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 1.4×10^{-2} curie of radon-220, 4.6×10^{-6} curie of radon-222, and very small quantities of xenon-127 (TRW 1999a, page 75). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger excavated volume, with more radon emanations from the repository walls and greater quantities exhausted by ventilation. The estimated differences in radon releases between the thermal load scenarios would be a function of the excavated repository volume, the exhaust ventilation flowrate, and the repository air exchange rate; the packaging scenario would not affect radon releases. The low thermal load scenario would have the largest excavated volume, largest exhaust flowrates and, therefore, the largest radon release. Appendix G, Section G.2, contains more information on repository volume, flowrates, and radon releases for the three thermal load scenarios.

Table 4-4 lists estimated annual doses and doses from 24 years of emplacement activities to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. Appendix G, Section G.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be small contributors to the overall public dose in comparison to radon-222 decay products from the subsurface facilities. All the radionuclides released from the surface facilities would be very small contributors to the overall public dose with the largest, krypton-85, contributing less than 0.001 percent of the dose to the public and noninvolved workers.

The dose to the offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be 19, 22, or 44 millirem for the 24 years of emplacement and development activities under the high, intermediate, or low thermal load scenario, respectively. For comparison, the annual dose to the offsite maximally exposed individual would be about 8, 9, or 18 percent, respectively, of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit does not apply to radon releases. The population dose would be 99, 120, or 230 person-rem, respectively. The dose to members of the public would vary by thermal load scenario but not by packaging scenario because naturally occurring radon-222 released from the subsurface would be the dominant dose contributor. Releases from surface facilities during spent nuclear fuel handling would make very small differences in the dose received.

The median dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 82 millirem for 24 years of emplacement activities,

Table 4-4. Estimated radiation doses for maximally exposed individuals and populations during handling, emplacement, and development activities during operation and monitoring phase.[a,b]

Impact	Thermal load: High Total	High Annual average[c]	Intermediate Total	Intermediate Annual average	Low Total	Low Annual average
Dose to public						
Offsite MEI[d] (millirem)	19	0.78	22	0.93	44	1.8
80-kilometer population[e] (person-rem)	99	4.1	120	4.9	230	10
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[f] (millirem)	82	3.4	82	3.4	82	3.4
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)						
Uncanistered scenario	63	2.6	75	3.1	140	5.7
Disposable canister scenario	62	2.6	74	3.1	130	5.6
Dual-purpose canister scenario	62	2.6	74	3.1	130	5.6
Nevada Test Site noninvolved worker population[h] (person-rem)	0.12	0.005	0.14	0.0059	0.27	0.012

a. Numbers are rounded to two significant figures.
b. Emplacement activities during the operation and monitoring phase would last 24 years, from 2010 to 2033. Continued subsurface development activities would last 22 years.
c. Annual average values reflect the increasing repository volume and radon release during subsurface development.
d. MEI = maximally exposed individual; about 20 kilometers (12 miles) south of the repository.
e. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Operations Area.
g. The analysis considered noninvolved workers at both the North and South Portal Operations Areas.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

regardless of the thermal load scenario. The doses would be constant across the thermal load scenarios because the volume of the development area ventilated in each scenario would be similar. The estimated number of noninvolved workers at the repository site, whom the analysis assumed would all be at the North Portal Operations Area, would vary among the packaging scenarios. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers for the uncanistered packaging scenario and about 1,000 workers for the disposable canister and dual-purpose canister packaging scenarios. There would be an estimated 70 additional workers at the South Portal Operations Area regardless of packaging scenario. The combination of the low thermal load scenario (which would have the largest radon release) and the uncanistered packaging scenario would result in the highest noninvolved worker population dose, 140 person-rem over the 24-year emplacement period. Workers at the South Portal Operations Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring and Maintenance Activities (2034 to 2110). Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would have minimal potential impact on air quality during monitoring and maintenance activities, except there would be a larger population of noninvolved workers employed for decontamination and these workers would be exposed to naturally occurring radon ventilated from the subsurface. The potential for releases of radionuclides from the surface facilities during these activities would be minimal and impacts would be very small.

Table 4-5 lists estimated annual doses and total doses that would occur over the 76 years of monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be 30, 36, or 88 millirem during monitoring and maintenance activities of the high, intermediate, or low thermal load scenario, respectively. For comparison, the annual dose to the offsite maximally exposed individual would be about 4, 5, or 13 percent, respectively, of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit would not apply to repository radon releases. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

Table 4-5. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases from subsurface monitoring and maintenance activities (including decontamination) during operation and monitoring phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual	Total	Annual	Total	Annual
Dose to public						
Offsite MEI[c] (millirem)	30	0.43	36	0.51	88	1.3
80-kilometer population[d] (person-rem)	160	2.1	190	2.5	470	6.2
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	2.0	0.039	2.3	0.046	5.8	0.12
Yucca Mountain noninvolved (surface) worker population (person-rem)						
Uncanistered scenario	0.14	0.025, 0.00087[f]	0.16	0.029, 0.0010[f]	0.40	0.072, 0.0026[f]
Disposable canister scenario	0.12	0.018, 0.00087[f]	0.14	0.021, 0.0010[f]	0.34	0.052, 0.0026[f]
Dual-purpose canister scenario	0.12	0.019, 0.00087[f]	0.14	0.022, 0.0010[f]	0.35	0.055, 0.0026[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.27	0.0035	0.32	0.0042	0.79	0.010

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of the 76 years of monitoring and maintenance activities, which would last until 2110.
c. MEI = maximally exposed individual; about 20 kilometers (12 miles) south of the repository. Values are for a 70-year lifetime.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Operations Area. Values are for a 50-year onsite working lifetime.
f. First value is for the 3 years of decontamination activities; second value is for the 73 years of monitoring and maintenance.
g. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The population dose for 76 years of monitoring and maintenance activities would be 160, 190, or 470 person-rem, respectively. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal, would be 2.0, 2.3, or 5.8 millirem for a 50-year working lifetime during monitoring and maintenance activities for the high, intermediate, or low thermal load scenario, respectively. The dose over 76 years to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would vary depending on the thermal load scenario and the packaging scenario. The combination of the low thermal load scenario (largest radon release) and the uncanistered packaging scenario (largest noninvolved worker population) would result in the highest noninvolved (surface) worker population dose, 0.40 person-rem for the 76-year monitoring and maintenance period. The extension of monitoring and maintenance activities to 276 years would extend these impacts to future generations of workers and the public. Section 4.1.7 discusses impacts to workers directly involved in monitoring and maintenance activities.

4.1.2.4 Impacts to Air Quality from Closure (2110 to 2125)

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin in 2110 and last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing (in a backfill preparation plant), and transfer of excavated rock to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from fuel consumption
- Particulate matter from a concrete batch plant
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land
- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the high, intermediate, and low thermal load scenarios.

Gaseous criteria pollutants would result primarily from vehicle exhaust. The low thermal load scenario would have somewhat higher emissions because of a larger vehicle fleet. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 5 percent of the regulatory limit for all three thermal load scenarios. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the muck pile would be cristobalite. Table 4-6 lists

Table 4-6. Estimated maximum criteria pollutant and cristobalite concentrations at the analyzed land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

			Maximum concentration[c]			Percent of regulatory limit		
			Thermal load			Thermal load		
Pollutant	Averaging time	Regulatory limit[b]	High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.080	0.13	0.12	0.080	0.13	0.12
Sulfur dioxide	Annual	80	0.0076	0.013	0.011	0.097	0.016	0.014
	24-hour	365	0.57	0.093	0.082	0.016	0.025	0.022
	3-hour	1,300	0.045	0.74	0.66	0.035	0.057	0.050
Carbon monoxide	8-hour	10,000	0.67	1.1	0.98	0.0065	0.011	0.0095
	1-hour	40,000	4.1	6.6	5.9	0.010	0.017	0.015
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.52	0.56	0.53	1.0	1.1	1.1
	24-hour	150 (65)	6.5	6.8	6.6	4.3	4.5	4.4
Cristobalite	[Annual[d]]	[10[d]]	0.010	0.014	0.0053	0.10	0.14	0.053

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.014 microgram per cubic meter or less for all three thermal load scenarios. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions between any of the scenarios.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Exposure to the noninvolved (surface) worker population and the public would occur during the 6-year period while this group was working on surface facility closure. For the low thermal load scenario, exposures to members of the public and noninvolved workers would occur during a 15-year period.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual about 20 kilometers (12 miles) south of the repository would be 2.6, 3.0, or 19 millirem for the 6, 6, or 15 years of closure activities under the high, intermediate, or low thermal load scenario, respectively. Although the limit does not apply to releases of radon, the annual dose to the offsite maximally exposed individual would be about 4, 5, or 12 percent, respectively, of the 10 millirem-per-year regulatory limit (40 CFR Part 61). The population dose would be 13, 15, or 93 person-rem, respectively, for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.24, 0.28, or 1.7 millirem, respectively, for

Table 4-7. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

Release	Thermal load: High Total	High Annual	Intermediate Total	Intermediate Annual	Low Total	Low Annual
Dose to public						
MEI[c] (millirem)	2.6	0.43	3.0	0.50	19	1.2
80-kilometer population[d] (person-rem)	13	2.1	15	2.5	93	6.2
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	0.24	0.039	0.28	0.046	1.7	0.12
Yucca Mountain noninvolved (surface) worker population (person-rem)						
Uncanistered scenario	0.041	0.0068	0.048	0.0080	0.12	0.020
Disposable canister scenario	0.029	0.0049	0.035	0.0058	0.086	0.014
Dual-purpose canister scenario	0.032	0.0053	0.037	0.0062	0.093	0.016
Nevada Test Site noninvolved worker population[f] (person-rem)	0.021	0.0035	0.025	0.0042	0.16	0.010

a. Numbers are rounded to two significant figures.
b. The closure phase would begin in 2110 and last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively.
c. MEI = maximally exposed individual; public MEI location would be 20 kilometers (12 miles) south of the repository.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Operations Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

the entire closure phase. The dose to the noninvolved repository (surface) worker population would vary depending on the thermal load and packaging scenarios. The combination of the low thermal load scenario (largest radon releases) and the uncanistered packaging scenario (largest noninvolved worker population) would result in the highest total noninvolved worker population dose, 0.12 person-rem.

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.
- Water demand under scenarios with the highest consumption would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. However, the highest demand scenario in combination with ongoing Nevada Test Site demand from the same basin would exceed the lowest estimates of perennial yield.
- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Desert in comparison to the quantities of water already being withdrawn there.
- The potential for flooding at the repository site is extremely small.

4.1.3.1 Impacts to Hydrology from Performance Confirmation

Performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-15). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River underground. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction period (2005 to 2010), and during the emplacement and development activities of the continuing construction, operation, and monitoring period that would follow (2010 to 2033), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DOE 1997i, pages 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization did not cause water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (Flint, Hevesi, and Flint 1996, pages 57 to 59), when combined with application rates measured during site characterization, show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operation and monitoring phase while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Operations Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-8 lists discharge estimates to the South Portal

Table 4-8. Annual water discharges to South Portal evaporation pond for thermal load scenarios.[a,b]

Phase	High thermal load	Intermediate thermal load	Low thermal load
Construction			
Discharge (cubic meters)[c]	8,400	10,000	10,000
Duration (years)	5	5	5
Operation and monitoring			
Discharge (cubic meters)	7,900	9,500	33,000
Duration (years)	22	22	22

a. Source: TRW (1999b, pages 6-9 and 6-18).
b. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.
c. To convert cubic meters to gallons, multiply by 264.18.

evaporation pond for the three thermal load scenarios. During the operation and monitoring phase, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. DOE would also investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. Water collected from the emplacement side of the subsurface area, if any, would also be pumped to this pond after verification that it was not contaminated. Table 4-9 lists discharge estimates to the North Portal evaporation pond for each packaging scenario during the operation and monitoring phase.

Table 4-9. Annual water discharges to North Portal evaporation pond during operation and monitoring phase for each packaging scenario.[a]

	Packaging scenario[b]		
Factor	UC	DISP	DPC
Discharge (million liters)[c]	30	25	25
Duration (years)	24	24	24

a. Source: TRW (1999a, page 75).
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. To convert liters to gallons, multiply by 0.26418.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (TRW 1998f, page 16). The North Portal evaporation pond, which is intended primarily for cooling and heating process water, would, at a minimum, have a polyvinyl chloride liner (TRW 1998f, pages 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. Section 4.1.4.2 discusses impacts to wildlife that could result from the presence of these ponds. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Other uses of water during the continuing construction, operation, and monitoring period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface from monitoring and maintenance activities and from closure would be similar to or less than those discussed for the initial construction period and emplacement and development activities. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A, *General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Restricted Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Restricted Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (TRW 1998f, pages 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. However, the inundation levels expected from a 100-year, 500-year, or regional maximum flood would represent little hazard to the proposed repository, the portals of which would be at higher elevations than the flood-prone areas (TRW 1999h, page 2-7).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a spill prevention, control, and countermeasures plan [Kiewit (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Restricted Area and one for the balance-of-plant facilities. The basin for the Restricted Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Both the South and North Portal Operations Areas would contain fuel-oil storage tanks. These tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [about 480 to 1,300 liters (130 to 330 gallons) a year] (TRW 1999a, page 74). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Restricted Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the continuing construction, operation, and monitoring period would be managed in the Restricted Area of the North Portal Operations Area. This would include the

Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components.

During the continuing construction, operation, and monitoring period a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DOE 1998a, Volume 2, page 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2 square kilometers (500 acres) of land would be disturbed during the construction and operation and monitoring phases (see Chapter 2). Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, one side of the proposed North Portal facilities is drained by Midway Valley Wash and the other is drained by Drill Hole Wash. The 0.6 square kilometer (150 acres) of disturbance at the North Portal area (of the total 2 square kilometers disturbed) would be small (less than 4 percent) in comparison to the estimated 18 square kilometers (4,400 acres) that comprise the drainage area for the Midway Valley and Drill Hole Washes by the time they reach the North Portal area (Bullard 1992, Table 5).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

If DOE received authorization to construct, operate and monitor, and close a geologic repository at Yucca Mountain, it would ship spent nuclear fuel and high-level radioactive waste to the repository for a period of about 24 years beginning in 2010. Some transportation-related construction, operation, and maintenance actions associated with the DOE proposal would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Other construction, operation, and maintenance actions could occur in floodplains or wetlands elsewhere in Nevada along one of five alternative rail corridors DOE could select to transport spent nuclear fuel and high-level radioactive waste to the repository. Construction, operation, and maintenance actions could also occur in floodplains or wetlands at one of three alternative intermodal transfer station sites in Nevada if DOE chose a heavy-haul truck route for transportation.

Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take to construct, operate, and maintain a branch rail line or highway route in the Yucca Mountain vicinity. The assessment analyzed the potential effects of these actions on the floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain.

The assessment in Appendix L presents a programmatic comparison of what is known about the floodplains, springs, and riparian areas along the five alternative rail routes and at the three alternative intermodal transfer station sites. In general, wetlands have not been delineated along the rail routes or at the three station sites. If DOE selected a rail corridor or heavy-haul truck route to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would prepare a detailed floodplain/wetlands assessment of the selected alternative.

Repository-related structures could affect small drainage channels or washes. DOE expects to address these other washes with minor diversion channels, culverts, or similar drainage control techniques.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the relatively short duration of the active life of the repository, which would include construction, operation and monitoring, and closure. The following impacts would be of primary concern during the active life of the repository:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer

- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository

- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff (as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (TRW 1999h, pages 2-19 to 2-21), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the North and South Portal Operations Areas, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DOE 1997j, all). This careful use of water in the subsurface would continue during repository construction activities. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be small and of minimal consequence to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill

Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction period and the continuing construction, operation, and monitoring period. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-10 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the thermal load scenario because the emplacement of less spent nuclear fuel (that is, low thermal load) per foot of repository tunnel would require more excavation. Water demand during these phases would also depend on the packaging scenario.

Table 4-10. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Proposed schedule	Water demand (acre-feet)[b] by thermal load		
		High	Intermediate	Low
Construction	2005 - 2010	150[c]	170[c]	170[c]
Operation and monitoring (by packaging scenario)				
Emplacement and development activities[d]	2010 - 2033			
Uncanistered		250	260	480
Disposable canister		220	230	450
Dual-purpose canister		220	230	450
Monitoring activities[e]	2033 - 2036			
Uncanistered		200	200	200
Disposable canister		160	160	160
Dual-purpose canister		160	160	160
Closure	2110 to varies			
Each packaging scenario		80	90	90

a. Source: TRW (1999a, pages 71, 74, 78, and 81); TRW (1999b, pages 6-3, 6-14, 6-21, 6-27, 6-28, and 6-37).
b. To convert acre-feet to cubic meters, multiply by 1,233.49.
c. Does not include water needed to construct a potential rail line.
d. Construction (or development) of the subsurface area during the operation and monitoring phase would take 22 years for the Proposed Action (emplacement would continue another 2 years). The values shown represent the highest demands projected for this phase and would occur during the period when both subsurface development and nuclear material emplacement were underway.
e. Values shown for monitoring activities are only applicable to the first 3 years (as shown by the schedule), when decontamination of surface facilities would be performed. Water demand for the 73 years that follow would be minimal.

As listed in Table 4-10, water demand during initial construction would range from about 0.19 million to about 0.21 million cubic meters (150 to 170 acre-feet) per year, depending on the thermal load scenario. Further, depending on the thermal load and packaging scenarios, demand during the emplacement and development period of the operation and monitoring phase could range from about 0.27 million to about 0.59 million cubic meters (220 to 480 acre-feet) per year. The first 3 years of the monitoring portion of the operation and monitoring phase would require water at a rate varying from 0.2 million to 0.25 million cubic meters (160 to 200 acre-feet) per year. The closure phase would require about 0.099 million to 0.11 million cubic meters (80 to 90 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the

Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by two methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water

During the initial construction period, the estimated water demand from the Jackass Flats Hydrographic Area would be about 0.53 million to about 0.55 million cubic meters (430 to 450 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 0.34 million cubic meters (280 acre-feet) a year (DOE 1998n, Table 11-2, page 11-6)]. This quantity is very similar to the roughly 0.49 million cubic meters (400 acre-feet) withdrawn from the Jackass Flats basin in 1996 (see Chapter 3, Table 3-15). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-16), during which elevation decreases as large as 12 centimeters (4.8 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

During the continuing construction, operation, and monitoring period, groundwater withdrawal rates would increase as listed in Table 4-10. When combined with the ongoing demand from the Nevada Test Site, these rates would be sufficiently larger than those tracked from current activities (see Chapter 3, Table 3-15).

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (Thiel 1997, page 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 0.37 million cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 0.72 million cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 0.72 million cubic meters (580 acre-feet). The highest estimated water demand during the continuing construction, operation, and monitoring period would not exceed this lowest estimate of perennial yield, and it would represent only about 12 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (Turnipseed 1992, pages 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 0.72 million cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 0.72 million cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 0.72 million cubic meters from the western portion of Jackass Flats would be unlikely to cause a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be too small to estimate or detect.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction period would be about 0.55 million cubic meters (450 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [0.72 million cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. However, repository water demands during the emplacement and development period (Table 4-10), when combined with the baseline demands from Nevada Test Site activities, would exceed the lowest perennial yield estimate under the low thermal load scenario for all packaging scenarios. The combined water demand under either the high or intermediate thermal load scenario would not exceed the lowest estimates of perennial yield. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek Ranch sub-basin, the heaviest water demand is in the Amargosa Desert. Over the long term, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (Buqo 1999, pages 37 and 51). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 0.55 million cubic meters (450 acre-feet) a year] and the operation and monitoring phase [about 0.93 million cubic meters (750 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities. Routine monitoring and maintenance activities would involve minimal water needs and, from a duration standpoint, would occupy most of the operation and monitoring phase.

The annual demand during closure for the high thermal load would be about one-third of that described for the high thermal load during the continuing construction, operation, and monitoring period and, similarly, would have minor impacts on groundwater resources.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Performance Confirmation

Performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance and sustained traffic could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

The desert tortoise, a threatened species, would continue to receive special consideration during land-disturbing activities at the site. DOE would continue to work with the Fish and Wildlife Service and implement the terms and conditions of the Biological Opinion for site characterization activities (Buchanan 1997, pages 19 to 24) to minimize impacts to desert tortoises at the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist of radioactive noble gases, principally isotopes of krypton and radon (TRW 1999a, page 75; see Section 4.1.2). These gases do not accumulate in the environment. The small quantities released would result in very small doses to plants and animals as the gases dispersed in the atmosphere. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). In a similar manner, assumed doses to plants and animals would be small and impacts from those doses would be unlikely to affect the population of any species because the doses would be much lower than the 100-millirad-per-day limit [for which there is no convincing evidence that chronic radiation exposure will harm plant or animal populations (IAEA 1992, page 54)]. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary between the thermal load scenarios (Table 4-11).

Table 4-11. Land cover types in the analyzed land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

	Total area		Area to be disturbed[d]		
Land cover type[c]	In Nevada	In the analyzed withdrawal area	Low thermal load	Intermediate thermal load	High thermal load
Blackbrush	9,900	140	0.36	0.02	0.02
Creosote-bursage	15,000	300	1.11	0.72	0.62
Mojave mixed scrub	5,700	120	0.03	0.86	0.80
Sagebrush	67,000	16	0	0	0
Salt desert scrub	58,000	20	0	0	0
Previously disturbed	NA[e]	4	0.48	0.37	0.37
Totals[f]	**NA**	**600**	**2.0**	**2.0**	**1.8**

a. Source: Facility diagrams from TRW (1999b, all) and land cover types maps (Utah State University 1996, Gap Data) and vegetation associations (TRW 1998c, page 9) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the pinyon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. As described in Chapter 2, the excavated rock pile would be in a different location for the low thermal load scenario.
e. NA = not applicable.
f. Totals might differ from sums due to rounding.

Six of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada (Utah State University 1996, Gap Data) occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-11). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-11). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in areas dominated by creosote-bursage and Mojave mixed scrub or blackbrush (under the low thermal load scenario) land cover types. These types are widespread in the analyzed land withdrawal area.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (TRW 1999k, pages 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of vegetation in disturbed areas.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (TRW 1999k, pages 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (TRW 1999k, page 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area. Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North and South Portal Operations Areas. Wildlife would be attracted to the water in these ponds to take advantage of this otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (Bechtel 1997, page 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 USC 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (TRW 1999k, pages 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (TRW 1997b, pages 6 to 12; TRW 1999k, page 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (TRW 1998h, pages 3 to 17; TRW 1999k, page 3-12). All but one of the 28 individual relocations and both nest relocations were successful. From 1989 to 1998, five tortoises (including the one unsuccessful relocation) were killed as a result of site characterization activities; all were killed by vehicles on roads (TRW 1999k, page 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases. As required by Section 7 of the Endangered Species Act, DOE has initiated consultations with the Fish and Wildlife Service on the desert tortoise. The result of these consultations will be a Fish and Wildlife Service Biological Opinion containing terms and conditions for protection of the desert tortoise during repository construction and operation.

The bald eagle (threatened) and peregrine falcon (endangered, but proposed for delisting) have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani's dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani's dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, low, moderate, or high, as listed and described in Table 4-12.

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- Soil recovery from disturbances

Table 4-12. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 2 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 2 square kilometers = 500 acres.

- Potential for spreading contamination by relocating contaminated soils (if present)
- Structural stability of existing soils and their ability to support the proposed activities

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removes vegetation or otherwise breaks up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities at the repository during the construction and operation and monitoring phases would disturb no more than about 2 square kilometers (500 acres) of land, including the excavated rock (see Chapter 2).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (TRW 1999l, pages 6 and 7). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during the phases of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DOE 1989a, pages 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DOE 1989a, all; DOE 1995g, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DOE 1989a, page 17; DOE 1995g, page 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would generally remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

> **SOIL RECOVERY**
>
> The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

Contamination

Based on characterization efforts and activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a spill prevention and control plan [Kiewit (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from performance confirmation, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Performance Confirmation

Land disturbances associated with performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region. Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if possible or, if it was not possible, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

4.1.5.2 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

Impacts to archaeological and historic sites could occur during the initial construction period and the continuing construction, operation, and monitoring period, when ground-disturbing activities would take place. Indirect impacts to archaeological and historic sites could occur during all phases of the Proposed Action.

Archaeological and Historic Resources

Potential impacts to *National Register*-eligible cultural resources from surface facility construction could occur in areas where ground-disturbing activities would take place. Repository development would disturb a maximum of about 2 square kilometers (500 acres) of previously undisturbed land at the site.

Archaeological investigations conducted in the immediate vicinity of the proposed surface facilities in support of previous and ongoing characterization studies and infrastructure construction have identified 826 archaeological and historic sites. These investigations have identified resource localities and provided mitigative relief for resources potentially subject to direct impacts (TRW 1999m, Table 2). In addition, ground-disturbing activities associated with potential nearby project actions (for example, upgrades to utility and road rights-of-way, rail access facilities, muck and other onsite storage areas) would occur in areas that had undergone field inventories and evaluations of cultural resources. Because the proposed locations of facilities and support areas are away from known archaeological sites, no direct impacts to known resources would occur.

Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Preliminary results from the monitoring of archaeological sites in the vicinity of Yucca Mountain activities since 1991 indicate that human activities and increased access could result in harmful effects, both advertent and inadvertent, to these fragile resources (TRW 1999m, Chapter 1). Indirect impacts are difficult to quantify and control, but they can include loss of surface artifacts due to illicit collection and inadvertent destruction (TRW 1999m, Chapter 1).

Even though there could be some indirect adverse impacts, the overall effect of the repository on the long-term preservation of the archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Cultural resources in the area would be protected from most human intrusion.

Excavation activities at the repository site could unearth additional materials and features in areas that past archaeological surveys have examined only at the surface. Past surveys in the Yucca Mountain area indicated buried cultural materials at some sites with surface artifacts (TRW 1999m, Chapter 1). Thus, excavation activities could unearth previously undetected subsurface features or artifacts. If this happened, work would stop until a cultural resource specialist evaluated the importance of the discovery.

Native American Viewpoints

DOE would continue the existing Native American Interaction Program (see Chapter 3, Section 3.1.6.2) throughout the Proposed Action. This program promotes a government-to-government relationship with associated tribes and organizations. Continuance of this program during the Proposed Action would enhance the protection of archaeological sites and cultural items important to Native Americans.

The Native American view of resource management and preservation is holistic in its definition of "cultural resource," incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation. Section 4.1.13.4 contains an environmental justice discussion of a Native American viewpoint on the Proposed Action.

Previous studies (Stoffle et al. 1990, all; AIWS 1998, all) have delineated several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. Construction activities for repository surface facilities would have no direct impacts on these locations. However, because of the general level of importance attributed to these places by Native Americans, and because they are parts of an equally important integrated cultural landscape, Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment (AIWS 1998, Chapter 2). In their view, the establishment of the protected area boundary and construction of the repository would continue to restrict the free access of Native American people to these areas. On the other hand, the Consolidated Group of Tribes and Organizations has recognized that past restrictions on public access due to site characterization have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (AIWS 1998, Chapter 2).

The potential for indirect impacts from construction activities and more workers in the area would increase, particularly to the physical evidence of past use of the cultural landscape (artifacts, cultural features, archaeological sites, etc.) important to Native American people. DOE would continue to provide training to workers to minimize the potential for indirect impacts.

Eventual closure of the repository would have the beneficial effect of returning much of the disturbed landscape to a natural setting. Some additional impacts could occur to resources or areas important to Native Americans if changes in land status or management that occurred after closure led to increased access by the public. The presence of a permanently entombed repository would represent an intrusion into what Native Americans consider an important cultural and spiritual place. Long-term monitoring features or activities would continue to affect these cultural viewpoints.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of the socioeconomic environment in communities near the proposed repository site considered changes to employment, economic measures, population, housing, and public services. The evaluation used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions and economic and population changes caused by the Proposed Action. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region and in the communities where most of the repository workers would live. As discussed in Chapter 3, Section 3.1.7, this region of influence consists of Clark, Lincoln, and Nye Counties in southern Nevada.

DOE established a bounding case to examine the maximum potential employment levels it would need to implement design features and packaging scenarios. The combination of the low thermal load scenario and the uncanistered packaging scenario would produce the highest incremental change in employment and have the greatest potential to affect the environment.

The analysis determined that no great socioeconomic impacts to any of the areas in the region of influence would be likely. Employment and population changes in the region of influence would not exceed one-half of 1 percent between the projected baseline (employment without the repository project) and the increase from the maximum employment case of the project.

4.1.6.1 Socioeconomic Impacts from Performance Confirmation

The level of employment for performance confirmation activities would be similar to or less than the current level for site characterization, as described in Chapter 3, Section 3.1.7. Because population and employment changes between ongoing site characterization activities and future performance confirmation activities would be imperceptible, there would be no meaningful impacts to housing or community services.

4.1.6.2 Socioeconomic Impacts from Construction, Operation and Monitoring, and Closure

4.1.6.2.1 *Impacts to Employment*

In 2006 and 2007, the peak years of employment during the initial construction period, about 1,640 workers would be employed on the Yucca Mountain Repository Project. Figure 4-2 shows composite (direct and indirect) employment changes by place of residence during the construction phase. Incremental

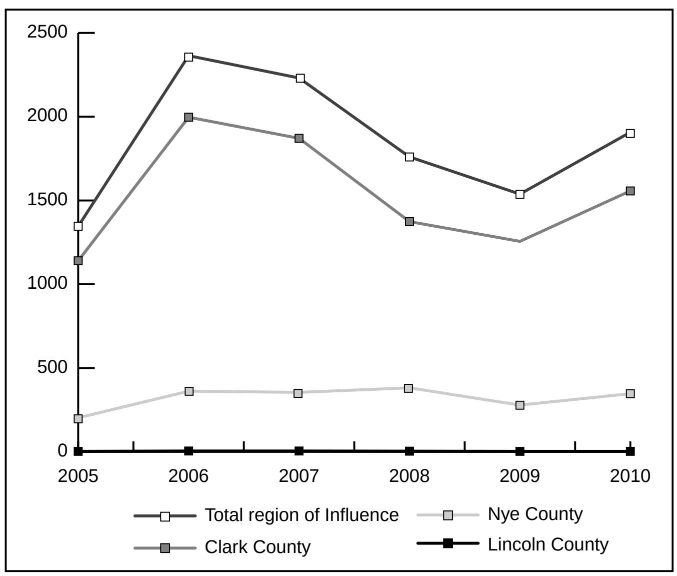


Figure 4-2. Increases in regional employment by place of residence during construction phase and onset of operation and monitoring phase: 2005 to 2010.

employment increases during the construction phase attributable to the repository would peak in 2006 with the addition of about 2,360 workers to the region of influence. This would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 946,000 to slightly less than 948,000, a change of less than one-quarter of 1 percent. Table 4-13 summarizes repository peak year employment during the initial construction period by employment category. Table 4-14 lists the expected residential distribution of construction phase workers, which in the first year would exceed 1,600 workers (2006). The table also lists the estimated peak number of indirect jobs created in these communities. These tables do not list Lincoln County because historically no workers have resided there. DOE expects that few, if any, repository employees would live in Lincoln County due to the long commute (TRW 1998d, all).

Table 4-13. Expected peak year (2006) increase in construction employment by place of residence in selected communities in Nye and Clark Counties.[a,b,c]

Location	Direct jobs	Indirect jobs	Total jobs
Clark County			
Indian Springs	48	29	72
Rest of Clark County	1,270	780	1,925
Clark subtotals	*1,318*	*809*	*1,997*
Nye County			
Amargosa Valley	22	5	25
Beatty	3	1	4
Pahrump area	294	68	333
Nye subtotals	*319*	*74*	*362*
Totals	***1,637***	***883***	***2,359***[d]

a. Employment and population impacts distributed using residential patterns of Nevada Test Site and Yucca Mountain employees from DOE (1994b, all).

b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County; includes approximately 5 indirect jobs in Lincoln County.

c. Employment in 2006 includes 161 current workers.

d. Does not include the 161 current workers.

Table 4-14. Repository direct workforce during construction phase by expected county of residence: 2005 to 2009.[a,b]

County	2005	2006	2007	2008	2009
Clark	795	1,317	1,093	1,093	1,128
Nye	193	320	311	267	274
Totals	**988**	**1,637**	**1,404**	**1,360**	**1,402**

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).

b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County.

Construction employment would begin to decline in 2008; in 2010 operational employment would start to increase and would peak in 2012. Employment after 2012 would be essentially stable with an average annual workforce of about 1,600 through 2035. Although operational phase peak employment would occur in 2012 (about 1,780 workers), the overall peak in incremental regional employment related to repository activities would occur earlier, in 2010. Usually the creation of indirect jobs and associated population increases occur after the creation of direct jobs. In this case, the region would still be experiencing the results of the incremental jobs created during the initial construction period. The net increase of about 140 peak year operational jobs over the peak year construction employment level would not affect the regional economy as noticeably as when the relatively small number of site characterization workers increased to more than 1,600 construction workers.

As mentioned above, in 2012, the peak year of employment during the continuing construction, operation, and monitoring period, about 1,780 workers would be employed on the Yucca Mountain Repository Project (TRW 1999a, Section 6; TRW 1999b, Section 6). As a consequence, the analysis included information on repository residential distribution and employment levels for 2010.

Table 4-15 lists the expected residential distribution of repository workers in the peak year, 2010. The table also lists the estimated number of indirect jobs created in these communities during 2010. The direct and indirect employment in the region of influence would peak with the addition of approximately 1,900 workers. This would result in a total increase in employment from the projected baseline of about 1,002,000 to about 1,004,000, a change of less than one-quarter of 1 percent. Table 4-16 summarizes repository employment through the first 35 years of the operation and monitoring phase by employment category. These tables do not list Lincoln County because historically no workers have resided there. As mentioned above, DOE expects that few workers would live in Lincoln County due to the long commute (TRW 1998d, all). Figure 4-3 shows the direct and indirect regional employment differences between the maximum employment case and the projected baseline.

Table 4-15. Expected peak year (2010) increases in operations employment in selected communities in Nye and Clark Counties.

Location	Direct jobs[a]	Indirect jobs	Total jobs
Clark County			
Indian Springs	64	11	56
Rest of Clark County	1,326	286	1,501
Clark subtotals	*1,421*	*297*	*1,557*
Nye County			
Amargosa Valley	23	3	24
Beatty	3	0	3
Pahrump	311	37	319
Nye subtotals	*337*	*40*	*346*
Totals	***1,727***	***337***	***1,903***[b]

a. Employment in 2010 includes 161 current workers.
b. Does not include the 161 current workers.

Table 4-16. Repository direct employment during operation and monitoring phase by county of residence: 2010 to 2035.

County	2010	2015	2020	2025	2030	2035
Clark total	1,390	1,365	1,379	1,365	1,322	1,161
Nye total	337	332	335	332	322	282
Totals	**1,727**	**1,697**	**1,714**	**1,697**	**1,644**	**1,443**

The completion of emplacement activities would result in a decline from about 1,560 emplacement workers in 2031 to about 1,440 decontamination and decommissioning workers from 2034 to about 2036 to 120 monitoring and maintenance workers from 2037 to 2110 employed at the Yucca Mountain site. However, even without the repository, the baseline projection predicts a continued increase in employment in the region of influence. If the present economic growth continued in the region of influence, it could absorb declines in the repository workforce.

After the completion of emplacement and decontamination of surface facilities, an annual employment of about 120 workers would be required for ongoing monitoring and maintenance activities. These activities could last as few as 26 years or as many as 276 years. This study assumed that monitoring would end in 2110, 100 years after the start of emplacement. Because monitoring and maintenance activities would require so few workers, no socioeconomic impacts would be likely.

The closure phase would be from 2110 to between 2116 and 2124, depending on the thermal load scenario. Projected peak employment for this phase would be approximately 520 workers (TRW 1999a, Section 6; TRW 1999b, Section 6). Employment would be far less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate changes to the labor force and economic measures of less than one-half of 1 percent. There probably would be no perceptible repository-induced changes to the baseline employment in the region of influence. Regional impacts during the closure phase probably would be small.

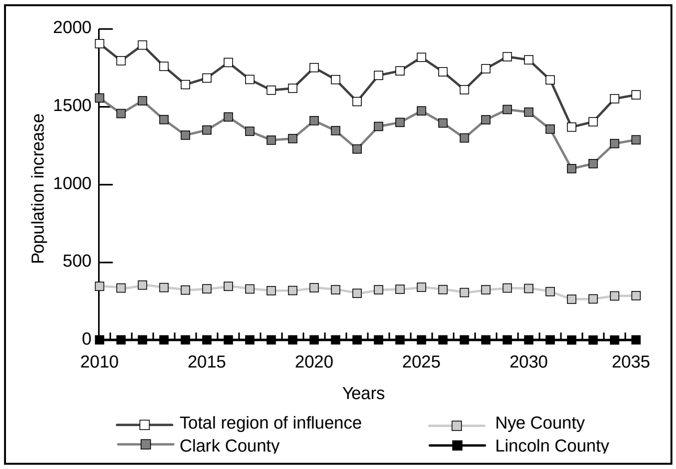


Figure 4-3. Increases in regional employment from operation and monitoring phase: 2010 to 2035.

4.1.6.2.2 *Impacts to Population*

From 2010, the projected year of peak employment, through 2035, the projected regional population will grow from about 1.9 million to more than 2.7 million people. The peak year population contribution attributable to the repository would be fewer than 4,000 people, a very small fraction of 1 percent. As a consequence, the Yucca Mountain Repository Project would be unlikely to alter the population growth to a great degree in the region of influence. Figure 4-4 shows the projected population increase as a result of the repository project.

Table 4-17 lists estimated incremental population increases that would occur as a result of repository activities to Clark and Nye Counties based on historic Nevada Test Site residential distribution patterns. As mentioned above, repository workers would be unlikely to reside in Lincoln County. The incremental population increase in Clark County would be almost imperceptible.

Table 4-17. Maximum expected population increase (2030).

Location	Population increase
Clark County	
Indian Springs	108
Rest of Clark County	2,882
Clark total	**2,990**
Nye County	
Amargosa Valley	50
Beatty	7
Pahrump	669
Nye total	**726**

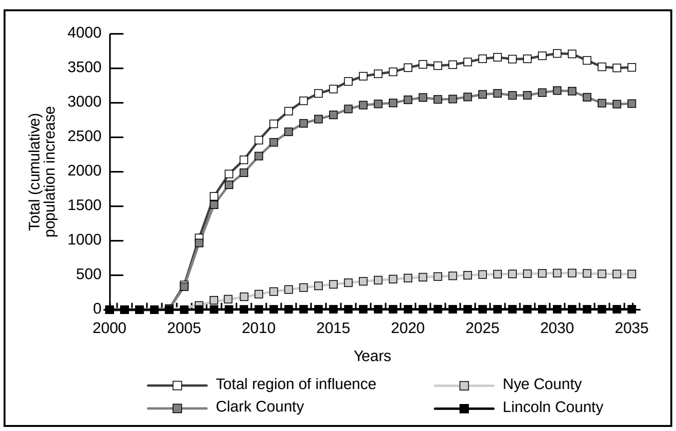


Figure 4-4. Regional population increases from construction and operations: 2000 to 2035.

The increase in the Nye County population would be less than 2 percent of the projected total population for the peak year for potential repository impacts. The Yucca Mountain Repository would not alter the population growth rate in Clark County in a measurable degree. Population growth associated with the repository would be more evident in Nye County. However, because the increases would occur over a long period, about 25 years, Nye County could accommodate them.

4.1.6.2.3 *Impacts to Economic Measures*

Table 4-18 lists changes in economic measures that would result from repository activities during the construction phase (expressed in 1992 dollars). The increases in real disposable income would peak in 2007 with an increase of about $57 million, while increases in Gross Regional Product would peak in 2006 at about $98 million. Regional expenditures by state and local governments would peak at $5.8 million in 2009. Economic measures for the region of influence would increase by less than one-quarter of 1 percent over the projected baseline (economic measures without the repository project).

Table 4-18. Increases in economic measures from repository construction: 2005 to 2009 (thousands of dollars).[a]

Jurisdiction	2005	2006	2007	2008	2009
Clark County					
Personal income	28,000	52,100	53,500	44,600	43,500
Gross Regional Product	46,500	84,000	79,100	59,400	47,800
State and local government expenditures	800	2,500	4,000	4,700	5,300
Nye County					
Personal income	1,700	3,100	3,100	2,400	2,800
Gross Regional Product	7,600	13,800	13,300	10,600	9,500
State and local government expenditures	100	200	300	400	500
Lincoln County					
Personal income	100	200	200	200	200
Gross Regional Product	100	100	100	100	100
State and local government expenditures	0	0	0	0	0
Total region of influence					
Personal income	29,800	55,400	56,800	47,200	46,500
Gross Regional Product	54,200	97,900	92,500	70,100	57,400
State and local government expenditures	900	2,700	4,300	5,100	5,800

a. Totals might differ from sums due to rounding.

GROSS REGIONAL PRODUCT

Value of goods and services produced in the region of influence.

Table 4-19 lists the changes in economic measures that would result from the repository project during the operation and monitoring phase. Increases in Gross Regional Product and in real disposable income would peak in 2029-2030, at about $70 million and $83 million, respectively. Increases in regional expenditures by state and local governments under the maximum employment case would also peak in 2030 at about $11 million. Economic measures for the region of influence would increase by less than one-half of 1 percent over the projected baseline.

4.1.6.2.4 *Impacts to Housing*

Repository-generated impacts to housing availability from changes in the population in the region of influence would be small. Given the size of the regional workforce, the number of workers inmigrating to work on the repository would be unlikely to be measurable.

The region of influence has an adequate supply of undeveloped land to meet future demands. Throughout most of the 1990s, the Bureau of Land Management has conducted land exchanges in Clark County. These exchanges have typically involved a trade of environmentally sensitive land outside the county for Bureau land in the county. The land in Clark County moves to the private sector for sale to land developers. This policy has helped to accommodate the population growth in the Las Vegas area.

Table 4-19. Increases in economic measures from emplacement and development activities: 2010 to 2035 (thousands of dollars).[a]

Jurisdiction	2010	2015	2020	2025	2030	2035
Clark County						
Personal income	53,200	57,400	64,300	70,300	74,700	73,000
Gross Regional Product	53,000	46,900	52,100	56,500	57,800	49,000
State and local government expenditures	5,900	7,700	8,400	8,800	9,100	8,800
Nye County						
Personal income	4,000	5,400	6,700	7,600	8,300	8,500
Gross Regional Product	11,000	10,600	11,400	11,900	11,800	10,000
State and local government expenditures	700	1,100	1,400	1,600	1,700	1,700
Lincoln County						
Personal income	200	200	200	200	300	200
Gross Regional Product	100	100	100	100	100	100
State and local government expenditures	0	100	100	100	100	100
Total region of influence						
Personal income	57,400	63,000	71,200	78,100	83,300	81,700
Gross Regional Product	64,100	57,600	63,600	68,500	69,700	59,100
State and local government expenditures	6,600	8,900	9,900	10,500	10,900	10,600

a. Totals might differ from sums due to rounding.

Workers and dependents who migrated to work on the repository probably would live in the many communities of Clark County, thereby dispersing the increased demand for housing. Southern Nye County, particularly Pahrump, would also experience some demand for housing. However, because the change in population would occur steadily over a long period, the county would be able to accommodate increases in housing demands. In Lincoln County, little or no demand would be likely, so housing availability would not be an issue.

4.1.6.2.5 *Impacts to Public Services*

Repository-generated impacts to public services from changes in the population in the region of influence would be small. Population changes in the region from the maximum repository-related employment case would be a small fraction of the anticipated job growth in the region. Even with the addition of repository jobs, the annual regional growth rate would increase by less than 2 percent, minimizing a possible need to alter plans already in place to meet projected growth.

As mentioned above, inmigrating workers probably would live in the many communities of Clark County, thereby dispersing the increased demand for public services. Southern Nye County, particularly Pahrump, also would experience some demand for public services. However, because the change in population would occur steadily over a long period, the county would be able to meet education, law enforcement, and fire protection demands. Impacts to public services would be unlikely in Lincoln County.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes short-term (prior to the completion of repository closure) health and safety impacts to workers (occupational impacts) and to members of the public from performance confirmation, construction, operation and monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved workers and noninvolved workers for each repository phase. Involved workers are craft and operations personnel who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste materials; and monitoring of the condition and performance of the waste packages. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in construction, excavation, and operations activities.

The evaluation used engineering estimates of equivalent full-time years worked during each phase along with standard statistics on industrial accidents and incidents to estimate impacts to workers from nonradiological hazards. It used a similar approach for radiological worker hazards. The evaluation used engineering estimates of pollutant releases from repository operations along with standard modeling techniques to estimate impacts to members of the public.

The types of human health and safety impacts estimated for workers would include those from industrial hazards, exposure to radiation and radioactive material, and exposure to hazardous nonradioactive material. The hazardous nonradioactive materials would be cristobalite and erionite, naturally occurring minerals in the rock (welded tuff) of the planned repository location. All of the estimated human health impacts to members of the public are based on airborne exposures to naturally occurring radioactive and hazardous materials. The radiological doses and hazardous material concentrations on which the human health impacts are based are described in Section 4.1.2.

Appendix F describes the methodology, data, and data sources used for the calculations of health and safety impacts to workers and supporting detailed results. In addition, it contains a human health impacts primer.

4.1.7.1 Impacts to Occupational and Public Health and Safety from Performance Confirmation (2001 to 2005)

Performance confirmation activities would be similar to the activities performed during Yucca Mountain site characterization. Their purpose would be to ensure that systems, operations, and materials were functioning as predicted. These activities could include the construction of surface facilities to support performance confirmation, excavation of exploratory tunnels, and testing and monitoring activities in the drifts. Chapter 3 describes site characterization activities and the resulting affected environment.

Potential health and safety impacts that could occur during performance confirmation activities include those common to an industrial work setting, radiological impacts to the public and workers from exposure to radon-222 and its decay products, external radiation exposure of workers in the subsurface environment, and the potential for exposure to naturally occurring cristobalite and erionite generated by excavation activities. Section 4.1.7.2 contains additional information on these potential exposure pathways. No spent nuclear fuel and high-level radioactive waste would be present during performance confirmation activities, so radiation exposure of workers from this source would not occur.

Impacts are likely to be very small during performance confirmation activities. Incremental health and safety impacts to workers for the performance confirmation period would be less than 2 percent of those estimated for the construction, operations and monitoring, and closure phases, based on comparisons of worker activities and the number of worker-years between site characterization (TRW 1994a, all) and repository activities (see Appendix F). Potential radiological impacts to members of the public would be less than those estimated for the construction phase (Section 4.1.7.2). The probability of latent cancer fatality in the offsite maximally exposed individual would be about 0.000001. No latent cancer fatalities (less than 0.007) would be likely in the potentially exposed population (see Section 4.1.7.2.2).

4.1.7.2 Impacts to Occupational and Public Health and Safety from Initial Construction (2005 to 2010)

This section describes estimates of health and safety impacts to repository workers and members of the public for the 5-year initial construction period (2005 to 2010). During this period, DOE would build the surface facilities, excavate the main drifts, and excavate enough emplacement drifts to support initial emplacement activities. Potential health and safety impacts to workers would occur from industrial hazards, exposure to naturally occurring radionuclides, and exposure to naturally occurring cristobalite and erionite in the rock at the Yucca Mountain site. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring radionuclides and hazardous materials.

4.1.7.2.1 *Occupational Health and Safety Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. The analysis estimated health and safety impacts to workers from hazards common to the industrial setting (such as falling or tripping) in which they would be working using statistics for similar kinds of operations and estimates of the total number of full-time equivalent worker years that would be involved in the activities. The statistics that the analysis used are from the DOE Computerized Accident/Incident Reporting and Recordkeeping System (DOE 1999c, all). These statistics reflect recent DOE experience for these types of activities. Appendix F, Section F.2.2.2, contains more information on the selection of impact statistics.

The analysis based its estimates for the number of full-time worker years for the construction phase on the current repository design concepts described in Chapter 2. Estimates range from about 5,200 to about 6,300 worker years depending on the thermal load and packaging scenario (Appendix F, Table F-1). Table 4-20 lists estimated potential impacts from normal industrial hazards for involved and noninvolved workers for the construction phase. The table lists three types of industrial safety impacts: total recordable cases of injuries and illnesses that are work-related, total lost workday cases, and fatalities. (See the discussions in Appendix F, Section F.2.2.)

Table 4-20. Estimated impacts to workers from industrial hazards during initial construction period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved workers									
Total recordable cases	290	240	250	300	250	260	300	250	260
Lost workday cases	140	120	120	140	120	120	140	120	120
Fatalities	0.14	0.11	0.12	0.14	0.12	0.12	0.14	0.12	0.12
Noninvolved workers									
Total recordable cases	50	41	42	50	41	42	50	41	42
Lost workday cases	24	20	21	24	20	21	24	20	21
Fatalities	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
All workers (totals)[f]									
Total recordable cases	340	280	290	350	290	300	350	290	300
Lost workday cases	160	140	140	160	140	140	170	140	140
Fatalities	0.18	0.15	0.16	0.18	0.16	0.16	0.18	0.16	0.16

a. Source: Appendix F, Tables F-7 and F-8.
b. The analysis assumed that construction phase would last 44 months for surface activities and 60 months for subsurface activities.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. Totals might differ from sums due to rounding.

The surface facilities that would be required to handle each packaging scenario would be different, so the industrial safety impacts for construction would be different. Appendix F, Tables F-7 and F-8, contains industrial hazard impact tables for surface and subsurface workers.

Estimated fatalities would be of the magnitude of 0.2 for all scenarios. Industrial safety impacts (including total recordable cases and lost workday cases) would be largest for the uncanistered packaging scenario due to the more extensive surface facilities required and, hence, more worker years for construction.

Naturally Occurring Hazardous Materials. Two types of naturally occurring hazardous materials are present at the Yucca Mountain site—cristobalite, a form of crystalline silica (silicon dioxide, SiO_2), and erionite, a naturally occurring zeolite. Both occur in the subsurface rock at Yucca Mountain and have the potential to become airborne during repository operations. Cristobalite, which would occur at the repository level, would be released during tunneling operations. It could also be released with wind-blown dust from the excavated rock pile.

Dust generated during tunneling would come from welded tuff, which consists largely of silica-based minerals. Crystalline silica is a highly structured form of silica that includes quartz and cristobalite. It is a known causative agent for the disease called *silicosis,* which is a destructive lung condition caused by deposition of particulate matter in the lungs and characterized by scarring of lung tissue. It is contracted by prolonged exposure to high levels of respirable silica dust or to acute levels of respirable silica dust (EPA 1996a, Chapter 8). The welded tuff has an average cristobalite content of between 18 and 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably will overestimate the airborne cristobalite concentration, because studies of both ambient and occupational airborne crystalline silica have shown that most airborne crystalline silica is coarse and not respirable, and that larger particles will deposit rapidly on the surface (EPA 1996a, page 3-26).

The International Agency for Research on Cancer has classified crystalline silica, when inhaled in the form of quartz or cristobalite from occupational sources, as a Class 1 (known) carcinogen (IARC 1997, pages 207 and 208). The Environmental Protection Agency has noted an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996a, pages 8-7 to 8-9). To date, the Environmental Protection Agency has not issued the factors needed to estimate the risk of cancer from crystalline silica exposures.

The dust from mechanical rock excavation and dust pickup from the excavated rock pile would consist of a range of particle sizes. Dust particles with an aerodynamic diameter smaller than 10 micrometers have little mass and inertia in comparison to their surface area; therefore, they can remain suspended in dry air for long periods and humans can inhale them. DOE would use engineering controls during subsurface work to control exposures of workers to silica dust. Water would be applied during excavation activities to wet both the rock face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that the water sprays did not suppress. The fresh air intake and the exhaust air streams would be separated to prevent increased dust concentrations in the drift atmosphere from recirculation. In addition, the ventilation system would be designed and operated to control ambient air velocities to minimize dust resuspension. DOE would monitor the working environment to ensure that workers were not exposed to dust concentrations higher than the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, subsurface workers would have to wear respirators until the engineering controls could establish acceptable conditions. Similar controls would be applied, if required, for surface workers. DOE expects that exposure of workers to silica dust would be below the applicable limits and potential impacts to subsurface and surface workers would be very small.

Erionite is a natural zeolite that occurs in the rock layers below the proposed repository level (see Chapter 3, Section 3.1.3). It might also occur in rock layers above the repository level but activities to date have not found it in those layers. Erionite could become a hazard during vertical boring operations if the operations passed through a rock layer containing erionite (which would be unlikely), and during excavation for access to the lower block as required for the low thermal load scenario. Erionite forms wool-like fibrous masses with a maximum fiber length of about 50 micrometers. The International Agency for Research on Cancer has determined that erionite is a carcinogen for humans, based on the very high mortality observed in three Turkish villages where erionite is mined (IARC 1987, all). DOE does not expect to encounter erionite layers either during vertical boring operations (which would be through rock layers above known erionite layers) or during excavation to provide access to the lower block and offset areas. Access excavation would be planned to avoid any identified layers of erionite (McKenzie 1998, all). If erionite was encountered during excavation for access to the lower block or during vertical boring operations, the engineering controls described above for cristobalite would be instituted and workers would be required to wear respiratory protection until acceptable conditions were reestablished. Appendix F, Section F.1.2, contains additional information on the impacts associated with inhalation of crystalline silica, cristobalite, and erionite.

Radiological Health Impacts. Potential radiological health impacts to involved and noninvolved workers in subsurface facilities during this phase would be from two sources: exposure to and inhalation of naturally occurring radon-222 and its decay products following emanation of the radon from the surrounding rock, and external radiation dose from naturally occurring radionuclides in the drift walls, principally potassium-40 and radionuclides in the uranium decay series (TRW 1999o, Sections 4 and 5). Radon-222 is a noble gas produced by the radioactive decay of naturally occurring uranium-238 in the rock. Because it is a noble gas, radon could emanate from the rock into the drifts, where elevated concentrations of radon-222 and its decay products could occur in the repository atmosphere (see Chapter 3, Section 3.1.8).

Studies during Exploratory Studies Facility activities indicated a dose rate from background sources of radionuclides in the drift walls of about 40 millirem per year, which is about the same as the cosmic and cosmogenic components from background radiation on the surface, 40 millirem per year in the Amargosa Valley region (see Chapter 3, Table 3-28). This analysis considers the underground ambient radiation dose to be part of the involved worker occupational exposure.

Workers in surface facilities would be exposed to airborne emissions of radon-222 and its decay products released in subsurface exhaust ventilation air. Spent nuclear fuel and high-level radioactive waste would not be present at the site during the construction phase and so would not contribute to radiological impacts.

Table 4-21 lists estimated potential doses and radiological health impacts for the 5 years of the construction phase to involved workers and noninvolved workers, and the sum for all workers. It lists estimated doses and radiological health impacts for the maximally exposed involved worker and for the involved worker population; radiological health impacts for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated collective dose and radiological health impacts for the combined population of workers. Estimated doses were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0004 latent cancer fatality per rem (see Appendix F, Section F.1.1.5). This conversion factor is based on a widely accepted international recommendation (ICRP 1991, page 22) and has been accepted for use by Federal agencies. The tables that follow list radiological health impacts for individuals as the increase in the probability of a latent cancer fatality occurring after the receipt of a dose for the maximally exposed individual worker.

Table 4-21. Estimated doses and radiological health impacts to workers during initial construction period.[a,b]

Worker group and impact category	High thermal load	Intermediate thermal load	Low thermal load
Involved workers			
Maximally exposed worker dose (millirem)	770	860	860
Latent cancer fatality probability	0.0003	0.0003	0.0003
Collective dose (person-rem)	350	420	420
Latent cancer fatality incidence	0.14	0.17	0.17
Noninvolved workers			
Maximally exposed worker dose (millirem)	580	640	640
Latent cancer fatality probability	0.0002	0.0003	0.0003
Collective dose (person-rem)	70	78	78
Latent cancer fatality incidence	0.03	0.03	0.03
All workers (totals)[c]			
Collective dose (person-rem)	420	500	500
Latent cancer fatality incidence	0.17	0.20	0.20

a. Source: Appendix F, Tables F-9 and F-10.
b. The construction phase would last 5 years. Results are for subsurface workers.
c. Totals might differ from sums due to rounding.

Radiological health impacts to populations are listed as the number of latent cancer fatalities estimated to occur in the exposed population.

During the initial construction period, radiological health impacts to the surface facility workforce would be much smaller than those to the subsurface facility workforce, so the numbers in Table 4-21 are those for subsurface workers (see Appendix F, Table F-5).

Table 4-21 indicates that the projected increase in the number of latent cancer fatalities for workers would be low (about 0.2); the calculated increase in the likelihood that an individual worker would die from a latent cancer fatality would also be low (less than about 0.0003).

4.1.7.2.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Table 4-1 lists estimated annual average concentrations of cristobalite at the site boundary where members of the public could be exposed during the construction phase. The analysis estimated concentrations of less than 0.025 microgram per cubic meter for all thermal load scenarios, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public during the construction phase would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. The analysis estimated doses and radiological health impacts for the offsite maximally exposed individual and the potentially involved population. The offsite maximally exposed individual is a hypothetical member of the public at a point on the land withdrawal boundary that would receive the largest annual dose and resultant radiological health impact. This location would be 20 kilometers (about 12 miles) south of the repository site. Section 4.1.2.2.2 provides additional information on the estimates of public doses. Estimated doses to members of the public were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0005 latent cancer fatality per rem for members of the public (see Chapter 3, Section 3.1.8).

Table 4-22 lists the estimated doses and radiological health impacts to members of the public from the 5-year initial construction period. The values in the table indicate that radiological health impacts to the public from repository construction would be very small (0.006 latent cancer fatality for each of the thermal load scenarios). The estimated individual risk of contracting a latent cancer fatality for the maximally exposed individual would be about 0.000001 over the 5-year phase.

Table 4-22. Estimated doses and radiological health impacts from radon-222 to the public during the initial construction period.[a,b]

Dose or health effect	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[c] dose (millirem)	2.1	2.5	2.5
Latent cancer fatality probability	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
Collective dose (person-rem)[d]	11	13	13
Latent cancer fatality incidence	0.0057	0.0066	0.0066

a. Source: Table 4-2.
b. The initial construction period would last 5 years.
c. The individual was assumed to maintain continuous residence 20 kilometers (12 miles) south of the repository.
d. Dose to approximately 28,000 individuals within about 80 kilometers (50 miles) of the repository.

4.1.7.3 Occupational and Public Health and Safety Impacts for the Continuing Construction, Operation, and Monitoring Period (2010 to 2110)

This section discusses estimates of health and safety impacts to workers and members of the public for the operation and monitoring phase. The analysis assumed a 24-year period for the receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste. There would be a concurrent 22-year period for drift development. A 76-year monitoring period would begin after the completion of emplacement. However, the monitoring period could be as short as 26 years and as long as 276 years (see Section 4.1). Appendix F, Table F-24, lists radiological health impacts for the shorter and longer monitoring periods.

4.1.7.3.1 *Occupational Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. Table 4-23 summarizes health and safety impacts from common industrial hazards for the operation and monitoring phase. DOE performed separate analyses for surface operations, subsurface emplacement operations, subsurface drift development operations, and monitoring activities, and summed the values to obtain the results listed in this table. Appendix F (Tables F-11, F-12, and F-13) contains results of the impact analysis for each subphase.

The analysis predicted a range of 1.3 to 1.6 fatalities for the various combinations of thermal load scenarios and packaging scenarios. The largest number of workers (see Appendix F, Table F-1) and, therefore, the largest industrial health and safety impacts would be associated with the uncanistered packaging scenario.

Naturally Occurring Hazardous Material. As discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures such as respiratory protection to control and minimize impacts to workers from releases of cristobalite and erionite during the operation and monitoring phase.

Radiological Health Impacts. This section discusses the estimates of the radiological health impacts to workers for the operation and monitoring phase. The overall radiological health impacts, which are listed in Table 4-24, are a combination of impacts to surface workers during operation, impacts to subsurface workers during operations, and impacts to surface and subsurface workers during monitoring.

Table 4-23. Estimated impacts to workers from industrial hazards during the continuing construction, operation, and monitoring period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[f]	1,360	1,150	1,160	1,360	1,150	1,160	1,400	1,180	1,200
LWC[g]	710	610	620	710	610	620	730	640	640
Fatalities	1.1	0.88	0.89	1.1	0.88	0.89	1.1	0.90	0.92
Noninvolved									
TRC	500	450	450	500	450	450	500	450	450
LWC	250	220	220	250	220	220	250	220	220
Fatalities	0.49	0.43	0.43	0.49	0.43	0.43	0.49	0.42	0.43
All workers (totals)[h]									
TRC	1,860	1,590	1,600	1,860	1,600	1,610	1,900	1,630	1,650
LWC	960	830	840	960	840	840	980	860	860
Fatalities	1.6	1.3	1.3	1.6	1.3	1.3	1.6	1.3	1.4

a. Source: Appendix F; sum of impacts listed in Tables F-11, F-12, F-13, F-19, F-20, and F-21.
b. The operation and monitoring phase would last 100 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. TRC = total recordable cases of accident or injury.
g. LWC = lost workday cases.
h. Totals might differ from sums due to rounding.

Table 4-24. Estimated dose and radiological health impacts to workers for the continuing construction, operation, and monitoring period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[f]	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[g] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[h]	8,120	5,330	5,380	8,450	5,660	5,710	8,530	5,740	5,790
LCF incidence	3.2	2.1	2.2	3.4	2.3	2.3	3.4	2.3	2.3
Noninvolved									
MEI dose	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD	350	330	330	380	360	360	400	390	390
LCF incidence	0.14	0.13	0.13	0.15	0.14	0.14	0.16	0.15	0.15
All workers (totals)[i]									
CD	8,470	5,660	5,710	8,830	6,020	6,070	8,930	6,130	6,180
LCF incidence	3.3	2.2	2.2	3.6	2.4	2.4	3.6	2.5	2.5

a. Source: The maximally exposed individual and latent cancer fatality probabilities are the maximums from Tables 4-25, 4-26, and 4-27. The collective dose and latent cancer fatality incidence are summed from the same tables.
b. The operation and monitoring phase would last 100 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. MEI dose = maximally exposed individual (worker) dose, in millirem. The subsurface facilities workers could incur the dose shown during the monitoring period.
g. LCF = latent cancer fatality.
h. CD = collective dose (person-rem).
i. Totals might differ from sums due to rounding.

With respect to overall radiological health impacts, the estimated health impacts to workers for the 100-year operation and monitoring phase would range from 2 to 4 latent cancer fatalities. Estimated radiological health impacts to the maximally exposed individual would be about the same as those from normal background radiation exposure in the Amargosa Valley region over a 70-year lifetime (about 25,000 millirem) during the 100-year operation and monitoring phase.

Tables 4-25 and 4-26 list health impacts to surface and subsurface workers, respectively, for 24 years of operations activities. Radiological health impacts to surface workers would be independent of the thermal load scenarios, and impacts to subsurface workers would be independent of the packaging scenario.

Table 4-25. Estimated dose and radiological health impacts to surface facility workers for the 24-year operation period.[a]

Worker group and impact category	Packaging scenario[b]		
	UC	DISP	DPC
Involved workers			
Maximally exposed worker dose (millirem)	9,600	9,600	9,600
LCF[c] probability	0.004	0.004	0.004
Collective dose (person-rem)	5,170	2,460	2,500
LCF incidence	2.1	1.0	1.0
Noninvolved workers			
Maximally exposed worker dose (millirem)	600	600	600
LCF probability	0.0002	0.0002	0.0002
Collective dose (person-rem)	100	90	90
LCF incidence	0.04	0.04	0.04
All workers (totals)[d]			
Collective dose (person-rem)	5,270	2,550	2,590
LCF incidence	2.1	1.0	1.0

a. Calculated from full-time equivalent worker year values in Appendix F, Table F-1 and dose rate values in Table F-5.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. LCF = latent cancer fatality.
d. Totals might differ from sums due to rounding.

Table 4-26. Estimated dose and radiological health impacts to subsurface facilities workers during the 24-year operation period.[a]

Worker group and impact category	High thermal load	Intermediate thermal load	Low thermal load
Involved			
Maximally exposed worker dose (millirem)[b]	7,010	7,630	7,630
LCF[c] probability	0.003	0.003	0.003
Collective dose (person-rem)	900	950	1,010
LCF incidence	0.36	0.38	0.40
Noninvolved			
Maximally exposed worker dose (millirem)[b]	980	1,270	2,280
LCF probability	0.0004	0.0005	0.0009
Collective dose (person-rem)	120	120	140
LCF incidence	0.05	0.05	0.06
All workers (totals)[d]			
Collective dose (person-rem)	1,020	1,070	1,150
LCF incidence	0.41	0.43	0.46

a. Source: Appendix F; sum of impacts listed in Tables F-14, F-15, F-16, F-17, and F-18. The impacts listed would result from work lasting 22 to 24 years.
b. The subsurface facilities emplacement workers could incur the dose shown during the 24-year operation period (the development worker's maximum worker dose would be lower).
c. LCF = latent cancer fatality.
d. Totals might differ from sums due to rounding.

The basic dose rate data (Appendix F, Table F-5) used to calculate radiological impacts are conservatively high, particularly for workers in surface facility operations, and tend to overestimate potential impacts. These estimates are sufficiently conservative to include potential doses from other activities such as handling low-level radioactive waste generated during repository operations. The principal contributors to radiological health impacts would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement, and subsurface monitoring activities (see Tables 4-25, 4-26, and 4-27). Radiological health impacts to workers would be highest for the combination of the uncanistered package scenario and the low thermal load scenario, with estimated radiological health impacts varying by about 50 percent from highest to lowest. Radiological health impacts from this combination of scenarios would be highest because it would involve the highest number of worker years. The variations are not large for a given shipping package scenario because impacts to subsurface workers would not depend on the shipping package scenario.

The largest component of the radiological impacts to subsurface workers during emplacement would be from inhalation of radon-222 and its decay products, particularly during the postemplacement monitoring period (see Appendix F, Table F-23).

Decontamination, Monitoring, and Maintenance Activities (2034 to 2110). The monitoring and maintenance activities of the operation and monitoring phase would last for 76 years and involve two types of activities leading to potential radiological health impacts. They are the decontamination of the surface facilities, which would take 2 to 3 years at the beginning of the monitoring period, and subsurface monitoring and maintenance activities. Table 4-27 lists estimated dose and radiological health impacts to workers for the surface facilities decontamination activities and the 76-year monitoring period.

Table 4-27. Estimated dose and radiological health impacts to workers for the 3-year decontamination period and the 76-year monitoring and maintenance period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[f] (millirem)	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[g] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[h] (person-rem)	2,050	1,990	1,980	2,330	2,250	2,260	2,350	2,270	2,280
LCF incidence	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.0	1.0
Noninvolved									
MEI dose (millirem)	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD (person-rem)	120	120	120	150	150	150	160	160	160
LCF incidence	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
All workers (total)[i]									
CD (person-rem)	2,170	2,110	2,100	2,480	2,400	2,410	2,510	2,430	2,440
LCF incidence	1.0	1.0	1.0	2.1	1.0	1.0	1.1	1.0	1.0

a. Sources: Appendix F, Tables F-22 and F-23.
b. Monitoring period impacts would be independent of the packaging scenario; surface facility decontamination impacts would depend on the packaging scenario.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. MEI dose = maximally exposed individual (worker) dose, in millirem.
g. LCF = latent cancer fatality.
h. CD = collective dose.
i. Totals might differ from sums due to rounding.

Appendix F, Table F-22 lists the radiological health impacts associated with surface facility decontamination operations. The impacts would vary with the packaging scenario because of differences in the surface facility design to accommodate the different types of shipping packages.

Monitoring and maintenance would involve both surface and subsurface workers; however, the dose to surface workers would be very low in comparison to those to subsurface workers. Therefore, essentially all the radiological impacts would be to subsurface workers (see Appendix F, Table F-5 footnotes). Appendix F, Table F-23, lists doses and radiological health impacts to subsurface workers for the 76-year monitoring period. Estimated doses and radiological health impacts to the maximally exposed worker are based on a 50-year working lifetime. In addition, Appendix F describes dose and radiological health estimates for workers for a shorter monitoring period of 26 years and for a longer monitoring period of 276 years (see Appendix F, Table F-24).

4.1.7.3.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of about 0.015 microgram per cubic meter or less for all thermal load scenarios. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from the operation and monitoring phase could result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air, and from exposure to radioactive noble gas fission products, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations. Krypton-85 and other noble gas fission products would be very small contributors to dose and potential radiological impacts, less than 0.001 percent of the dose from radon-222 and its decay products (see Section 4.1.2.3.2).

Section 4.1.2.3.2 presents estimates of dose to the public for the continuing construction, operation, and monitoring period. Table 4-28 lists these doses and potential radiological health impacts to the public for that period.

Table 4-28. Estimated total dose and radiological health impacts over 50 years to the public for continuing construction, operation, and monitoring period.[a]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[b] dose (millirem)	49	58	132
Latent cancer fatality probability	2.45×10^{-5}	2.3×10^{-5}	6.6×10^{-5}
Collective dose[c] (person-rem)	259	310	700
Latent cancer fatality incidence	0.13	0.15	0.35

a. Source: Tables 4-4 and 4-5.
b. Exposed for a 70-year lifetime; assumed first 24 years during operation and last 46 years during monitoring.
c. Dose to approximately 28,000 individuals within about 80 kilometers (50 miles) for 100 years of operation and monitoring.

Potential radiological health impacts to the public from radionuclides released during the operation and monitoring phase would be low, with 0.13 to 0.35 latent cancer fatality estimated for the thermal load scenarios. The probability of a latent cancer fatality to the maximally exposed individual would be about 0.00005 or less.

4.1.7.4 Impacts to Occupational and Public Health and Safety from Closure (2110 to 2125)

This section contains estimates of health and safety impacts to workers and to members of the public for the closure phase. The length of this phase would depend on the thermal load scenario. The values used for impact estimates are 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively.

4.1.7.4.1 *Occupational Impacts (Involved and Noninvolved Workers*)

Industrial Hazards. Table 4-29 lists impacts to workers from normal industrial workplace hazards for the closure phase.

Table 4-29. Estimated impacts to workers from industrial hazards during closure phase.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[f]	180	150	150	180	150	150	300	270	270
LWC[g]	85	71	74	85	71	74	140	130	130
Fatalities	0.08	0.07	0.07	0.08	0.07	0.07	0.14	0.13	0.13
Noninvolved									
TRC	28	24	23	28	23	24	41	36	37
LWC	14	11	12	14	11	12	20	18	18
Fatalities	0.03	0.02	0.02	0.03	0.02	0.02	0.04	0.03	0.03
All workers (totals)[h]									
TRC	210	170	170	210	170	170	340	310	310
LWC	99	82	86	99	82	86	160	150	150
Fatalities	0.11	0.09	0.09	0.11	0.09	0.09	0.18	0.16	0.16

a. Source: Appendix F, Tables F-25 and F-26.
b. The closure phase would last for 6, 6, and 15 years for high, intermediate, and low thermal loads, respectively (Jessen 1999a).
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. TRC = total recordable cases.
g. LWC = lost workday cases.
h. Totals might differ from sums due to rounding.

The estimated number of impacts from industrial hazards for the low thermal load scenario would be about double those for the intermediate and high thermal load scenarios because of the longer time required for closure and the associated larger number of worker years. The estimated number of fatalities would be much less than 1 for all thermal load scenarios.

Naturally Occurring Hazardous Material. Subsurface excavation would not occur during the closure phase, so the potential for exposure of workers to cristobalite and erionite would be much less. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.2 for the construction phase to control and minimize potential impacts to workers.

Radiological Health Impacts. During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation emanating from the waste packages. Table 4-30 lists radiological impacts to workers for the closure phase. Because estimated doses and radiological impacts to surface workers would be

Table 4-30. Estimated dose and radiological health impacts to workers during closure phase.[a,b]

Worker group and impact category	High thermal load (6 years)	Intermediate thermal load (6 years)	Low thermal load (15 years)
Involved			
Maximally exposed individual dose[c] (millirem)	2,040	2,370	5,520
Latent cancer fatality probability	0.0008	0.0009	0.002
Collective dose (person-rem)	380	450	1,100
Latent cancer fatality incidence	0.15	0.18	0.44
Noninvolved			
Maximally exposed individual dose[c] (millirem)	1,090	1,340	3,540
Latent cancer fatality probability	0.0004	0.0005	0.001
Collective dose (person-rem)	48	59	160
Latent cancer fatality incidence	0.02	0.02	0.06
All workers (totals)[d]			
Collective dose (person-rem)	430	510	1,260
Latent cancer fatality incidence	0.17	0.20	0.50

a. Source: Appendix F, Tables F-27, F-28, and F-29.
b. Closure phase would last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively (Jessen 1999a, all).
c. The subsurface facilities workers could incur the dose listed during the closure phase.
d. Totals might differ from sums due to rounding.

much smaller than those for subsurface workers (see Appendix F, Table F-5 footnotes), the impacts listed in this table are those for subsurface workers, which would be independent of the packaging scenario.

For the closure phase, the estimated number of latent cancer fatalities would range from 0.2 to 0.5. The probability of a latent cancer fatality for the maximally exposed individual worker would be 0.002 or less. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

4.1.7.4.2 *Public Health Impacts*

Naturally Occurring Hazardous Material. Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.015 microgram per cubic meter or less were estimated for all thermal load scenarios, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-31 lists the estimated dose and radiological health impacts.

Radiological health impacts to the public would be low. The likelihood that the maximally exposed individual would experience a latent cancer fatality would be in the range of 0.000001 to 0.00001. The projected number of latent cancer fatalities would be 0.05 or less. The radiological health impacts to the public would be independent of the packaging scenario. Impacts to the public would be greatest for the low thermal load scenario, and would be about 6 to 7 times greater than for the intermediate and high thermal loads because of the larger radon release associated with the longer closure period for the low thermal load scenario.

Table 4-31. Estimated dose and radiological health impacts to public for the closure phase.[a]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[b] dose (millirem)	2.6	3.1	19
Latent cancer fatality probability	1.3×10^{-6}	1.5×10^{-6}	9.4×10^{-6}
Collective dose (person-rem)[c]	13	15	93
Latent cancer fatality incidence	0.0064	0.0076	0.047

a. Source: Table 4-7.
b. For a person maintaining continuous residency during the entire closure phase.
c. Dose to approximately 28,000 individuals living within about 80 kilometers (50 miles).

4.1.7.5 Summary of Impacts to Occupational and Public Health and Safety

This section summarizes the potential human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases for (1) impacts to workers from industrial hazards; (2) radiological health impacts to workers; and (3) radiological health impacts to members of the public. The three project phases would last 111, 111, and 120 years for the high, intermediate, and low thermal load scenarios, respectively. These differences in project duration are due to differences in the length of the closure phase for the three thermal load scenarios as described above.

4.1.7.5.1 *Impacts to Workers from Industrial Hazards in the Workplace for All Phases*

Table 4-32 lists the total impacts to workers from industrial hazards common to the workplace for all phases. For the approximately 110 to 120 years of repository activities, the estimated number of workplace fatalities would range from about 1.5 to 2. The estimated number of lost workday cases due to industrial injury or illness would range from about 1,060 to 1,280, depending on the combination of thermal load scenario and packaging scenario. About half of the industrial impacts would come from surface facility operations during the operation and monitoring phase because of the large number of worker years needed. The next largest contribution would be drift development during the operation and monitoring phase, which would account for as much as 15 percent of the impacts. The differences in impacts for the thermal load and shipping package combinations reflect differences in the number of full-time equivalent workers for the potential combinations.

4.1.7.5.2 *Radiological Impacts to Workers for All Phases*

Table 4-33 lists the total dose and radiological health impacts to workers for all phases. It lists dose and the potential radiological health impact to the maximally exposed individual worker for a 50-year working lifetime, and collective dose and potential radiological health impacts to the worker population for the 111, 111, or 120 years required to complete all phases for the high, intermediate, and low thermal load scenarios, respectively. The maximally exposed worker would have a probability of incurring a latent cancer fatality of 0.006 to 0.008 from radiation exposure over a 50-year working lifetime. The total estimated number of latent cancer fatalities in the repository workforce from the radiation exposure during all phases would range from about 2.5 to 4, depending on the combination of thermal load scenario and packaging scenario.

About 50 percent of the total worker radiation dose would be from the receipt, handling, and packaging of spent nuclear fuel in the surface facilities. Radiation from inhalation of radon-222 and its decay products by subsurface workers during construction, development, emplacement, monitoring, and closure

Table 4-32. Estimated impacts to workers from industrial hazards for all phases.[a]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[e]	1,820	1,540	1,560	1,830	1,550	1,570	1,990	1,700	1,730
LWC[f]	930	800	810	930	810	820	1,010	890	900
Fatalities	1.3	1.1	1.1	1.3	1.1	1.1	1.4	1.2	1.2
Noninvolved									
TRC	570	510	520	570	510	520	590	520	530
LWC	280	250	260	280	250	260	290	260	260
Fatalities	0.54	0.48	0.49	0.54	0.48	0.49	0.55	0.50	0.50
All workers (totals)[g]									
TRC	2,390	2,050	2,080	2,400	2,060	2,090	2,580	2,220	2,260
LWC	1,210	1,050	1,070	1,210	1,080	1,080	1,300	1,150	1,160
Fatalities	1.8	1.6	1.6	1.8	1.6	1.6	2.0	1.7	1.7

a. Source: Sum of impacts listed in Tables 4-20, 4-23, and 4-29.
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. TRC = total recordable cases.
f. LWC = lost workday cases.
g. Totals might differ from sums due to rounding.

Table 4-33. Estimated dose and radiological health impacts to workers for all phases.[a]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[e]	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[f] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[g]	8,850	6,060	6,110	9,320	6,530	6,580	10,060	7,270	7,320
LCF incidence	3.5	2.4	2.4	3.7	2.6	2.6	4.0	2.9	2.9
Noninvolved									
MEI dose[e]	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD	460	450	450	510	500	500	640	620	620
LCF incidence	0.19	0.18	0.18	0.21	0.20	0.20	0.25	0.25	0.25
All workers (totals)[h]									
CD	9,310	6,510	6,560	9,830	7,030	7,080	10,700	7,890	7,940
LCF incidence	3.7	2.6	2.6	3.9	2.8	2.8	4.3	3.2	3.2

a. Source: Tables 4-21, 4-24, and 4-30.
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. MEI dose = maximally exposed individual (surface facility worker) dose, in millirem.
f. LCF = latent cancer fatality.
g. CD = collective dose (person-rem).
h. Totals might differ from sums due to rounding.

would account for about 25 percent of the total worker dose, with another 10 to 15 percent of the total dose coming from subsurface worker exposure to radiation emanating from the waste packages.

Estimated dose and radiological health impacts to workers would be highest for the low thermal load scenario, with estimates 30 to 40 percent higher than those for the high thermal load scenario, because of the larger number of projected worker years. Dose and radiological health impacts would be one-third more for the uncanistered packaging scenarios than those for the other packaging scenarios because of the larger number of projected worker years. Accordingly, the combination of the low thermal load scenario and the uncanistered packaging scenario would have the highest estimated collective worker dose (10,700 person-rem) and highest estimated radiological impacts (4.3 latent cancer fatalities) over 120 years of repository activities.

4.1.7.5.3 *Radiological Health Impacts to the Public for All Phases*

Table 4-34 lists the estimated dose and radiological health impacts to the public for all phases. It lists dose and the potential radiological impact to the offsite maximally exposed individual for a 70-year lifetime with continuous residency about 20 kilometers (12 miles) south of the repository, and collective dose and potential radiological health impacts to the population within about 80 kilometers (50 miles) for the 111, 111, or 120 years required to complete all phases for the high, intermediate, and low thermal load scenarios, respectively.

Table 4-34. Estimated dose and radiological impacts to the public for all phases.[a,b]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[c] (millirem)	38	46	100
Latent cancer fatality probability	1.9×10^{-5}	2.3×10^{-5}	5.1×10^{-5}
Collective dose[d] (person-rem)	280	340	810
Latent cancer fatality incidence	0.14	0.17	0.41

a. Source: Tables 4-22, 4-28, and 4-31.
b. Values are rounded to two significant figures.
c. Dose over a 70-year lifetime of the operation and monitoring phase, with continuous residency about 20 kilometers (12 miles) south of the repository.
d. Over all phases, lasting a total of 110, 111, or 120 years for the high, intermediate, or low thermal load scenario, respectively.

The offsite maximally exposed individual would have an increase in the probability of incurring a latent cancer fatality ranging from about 0.00002 to 0.00005 from exposure to radionuclides released from the repository facilities over a 70-year lifetime. The total estimated number of latent cancer fatalities in the potentially exposed population would range from 0.14 to 0.41 for the three thermal load scenarios. All doses and estimated radiological impacts would be from exposure to naturally occurring radon-222 and its decay products released from the subsurface facilities in exhaust ventilation air.

For comparison, the average individual radiation doses from natural sources of background radiation for Amargosa Valley and for the population of the United States are about 340 and 300 millirem per year, respectively (see Chapter 3, Table 3-28). Over a 70-year lifetime, individual dose from background radiation would be about 25,000 millirem, which is about 250 times larger than the offsite maximally exposed individual dose listed in Table 4-34. The highest annual dose to a member of the public from repository sources would be about 1.5 millirem or less. This radiation dose, essentially all from naturally occurring radon-222 and decay products, would be about 0.7 percent of the 200-millirem-per-year dose from radon-222 to members of the public in Amargosa Valley from ambient levels of naturally occurring radon (see Chapter 3, Section 3.1.8.2).

The Nevada cancer fatality rate in a population of 100,000 males is about 163 deaths per year (ACS 1998, page 6). Assuming this mortality rate is a baseline that would remain unchanged for the estimated population (in 2000) of about 28,000 within about 80 kilometers (50 miles) of the Yucca Mountain site, there would be about 50 cancer deaths per year from other causes and more than 5,000 cancer deaths over the period of the repository phases. The impact calculations in this EIS indicate that the additional cancer fatalities for the public from short-term activities would be less than 0.4, which would be an increase of about 0.01 percent.

4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual*, defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker*, a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

ACCIDENT TYPES

Radiological accidents are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.

Nonradiological accidents are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The impacts to offsite individuals from repository accidents would be small, with calculated doses as high as 0.013 rem to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher, bounded by the worst-case accident scenarios at 31 rem.

4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (plausible upper limit) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

The analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accident s. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate impacts.

The radionuclide source term for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix H contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a typical fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- *Involved worker.* A facility worker directly involved in activities at the location where the postulated accident could occur

- *Maximally exposed noninvolved worker (collocated worker).* A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs

- *Maximally exposed offsite individual.* A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be about 11 kilometers (about 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the frequency of wind in each direction enters the continuous release calculation of the maximally exposed individual.

- *Offsite population.* Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Sixteen accident scenarios were analyzed in detail. These scenarios bound the consequences of credible accidents at the repository. They include accidents in the Cask/Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, fuel canisters, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

Table 4-35 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-36 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from

Table 4-35. Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual		Population		Noninvolved worker		Involved worker	
Accident[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. 6.9-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	4.5×10^{-4}	1.9×10^{-3}	1.0×10^{-6}	5.5×10^{-2}	2.7×10^{-5}	9.4×10^{-1}	3.8×10^{-4}	76	3.0×10^{-2}
2. 7.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	6.1×10^{-4}	2.3×10^{-3}	1.2×10^{-6}	6.6×10^{-2}	3.3×10^{-5}	1.1	4.4×10^{-4}	90	3.6×10^{-2}
3. 4.1-meter drop of shipping cask in CTHA-61 BWR assemblies- no filtration	1.4×10^{-3}	1.3×10^{-3}	6.5×10^{-7}	3.9×10^{-2}	2.0×10^{-5}	5.7×10^{-1}	2.3×10^{-4}	46	1.8×10^{-2}
4. 4.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	1.9×10^{-3}	1.4×10^{-3}	7.0×10^{-7}	4.6×10^{-2}	2.3×10^{-5}	6.6×10^{-1}	2.6×10^{-4}	53	2.1×10^{-2}
5. 6.3-meter drop of MCO in CTS-10 N-Reactor fuel canisters-filtration	4.5×10^{-4}	3.7×10^{-7}	1.9×10^{-10}	1.1×10^{-5}	5.3×10^{-9}	1.1×10^{-4}	4.4×10^{-8}	(e)	(e)
6. 6.3-meter drop of MCO in CTS-10 N-reactor fuel canisters-no filtration	2.2×10^{-7}	1.2×10^{-3}	6.0×10^{-7}	3.4×10^{-2}	1.7×10^{-5}	3.6×10^{-1}	1.4×10^{-4}	(e)	(e)
7. 5-meter drop of transfer basket in ATS-8 PWR assemblies-filtration	1.1×10^{-2}	6.6×10^{-7}	3.3×10^{-10}	4.0×10^{-4}	2.0×10^{-7}	1.7×10^{-4}	6.8×10^{-8}	(e)	(e)
8. 5-meter drop of transfer basket in ATS-8 PWR assemblies-no filtration	2.8×10^{-7}	5.6×10^{-4}	2.8×10^{-7}	1.7×10^{-2}	8.6×10^{-6}	1.6×10^{-1}	6.4×10^{-5}	(e)	(e)
9. 7.6-meter drop of transfer basket in ATS-16 BWR assemblies-filtration	7.4×10^{-3}	5.1×10^{-7}	2.6×10^{-10}	2.9×10^{-4}	1.5×10^{-7}	1.3×10^{-4}	5.2×10^{-8}	(e)	(e)
10. 7.6-meter drop of transfer basket in ATS-16 BWR fuel assemblies-no filtration	1.9×10^{-7}	6.1×10^{-4}	3.1×10^{-7}	1.6×10^{-2}	8.2×10^{-6}	1.8×10^{-1}	7.2×10^{-5}	(e)	(e)
11. 6-meter drop of disposal container in DCHS-21 PWR assemblies-filtration	1.8×10^{-3}	1.8×10^{-6}	9.0×10^{-10}	1.0×10^{-3}	5.2×10^{-7}	5.0×10^{-4}	2.0×10^{-7}	(e)	(e)
12. 6-meter drop of disposal container in DCHS-21 PWR fuel assemblies-no filtration	8.6×10^{-7}	1.7×10^{-3}	8.5×10^{-7}	5.1×10^{-2}	2.5×10^{-5}	5.1×10^{-1}	2.0×10^{-4}	(e)	(e)
13. Transporter runaway and derailment in access tunnel-21 PWR assemblies-filtration-16-meter drop height equivalent	1.2×10^{-7}	4.3×10^{-3}	2.2×10^{-6}	1.1×10^{-1}	5.4×10^{-5}	1.5	6.0×10^{-4}	(f)	(f)
14. Earthquake - 375 PWR assemblies	2.0×10^{-5}	9.1×10^{-3}	4.6×10^{-6}	3.6×10^{-1}	1.8×10^{-4}	8.3	3.3×10^{-3}	(f)	(f)
15. Earthquake w/fire in WTB	2.0×10^{-5}	1.8×10^{-5}	9.0×10^{-9}	6.3×10^{-4}	3.2×10^{-7}	5.2×10^{-3}	2.1×10^{-6}	(f)	(f)
16. LLW drum rupture in WTB	0.59	6.1×10^{-10}	3.1×10^{-13}	2.1×10^{-8}	1.1×10^{-11}	1.4×10^{-7}	5.6×10^{-11}	7.0×10^{-5}	2.8×10^{-8}

a. Source: Appendix H.

b. CTHA = Cask Transfer/Handling Area, CTS = Canister Transfer System, ATS = Assembly Transfer System, DCHS = Disposal Container Handling System, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. LCFi is the likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers probable in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection as discussed in this section.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on current staffing projections (TRW 1998i, pages 17 and 18).

Table 4-36. Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

		Maximally exposed offsite individual		Population		Noninvolved worker		Involved worker	
Accident[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. 6.9-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	4.5×10^{-4}	7.2×10^{-3}	3.5×10^{-6}	1.7	8.6×10^{-4}	5.1	2.0×10^{-3}	76	3.0×10^{-2}
2. 7.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	6.1×10^{-4}	8.0×10^{-3}	4.0×10^{-6}	2.1	1.1×10^{-3}	5.9	2.4×10^{-3}	90	3.6×10^{-2}
3. 4.1-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	1.4×10^{-3}	4.3×10^{-3}	2.2×10^{-6}	1.3	6.5×10^{-4}	3.1	1.2×10^{-3}	46	1.8×10^{-2}
4. 4.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	1.9×10^{-3}	5.2×10^{-3}	2.6×10^{-6}	1.5	7.8×10^{-4}	3.5	1.4×10^{-3}	53	2.1×10^{-2}
5. 6.3-meter drop of MCO in CTS-10 N-Reactor fuel canisters-filtration	4.5×10^{-4}	1.2×10^{-6}	6.0×10^{-10}	2.6×10^{-4}	1.3×10^{-7}	3.3×10^{-4}	1.3×10^{-7}	(e)	(e)
6. 6.3-meter drop of MCO in CTS-10 N-reactor fuel canisters-no filtration	2.2×10^{-7}	4.3×10^{-3}	2.2×10^{-6}	8.6×10^{-1}	4.3×10^{-4}	1.1	4.4×10^{-4}	(e)	(e)
7. 5-meter drop of transfer basket in ATS-8 PWR assemblies-filtration	1.1×10^{-2}	2.5×10^{-6}	1.3×10^{-9}	3.3×10^{-2}	1.6×10^{-5}	4.6×10^{-4}	1.8×10^{-7}	(e)	(e)
8. 5-meter drop of transfer basket in ATS-8 PWR assemblies-no filtration	2.8×10^{-7}	2.1×10^{-3}	1.1×10^{-6}	5.6×10^{-1}	2.8×10^{-4}	4.6×10^{-1}	1.8×10^{-4}	(e)	(e)
9. 7.6-meter drop of transfer basket in ATS-16 BWR assemblies-filtration	7.4×10^{-3}	2.1×10^{-6}	1.1×10^{-9}	2.4×10^{-2}	1.2×10^{-5}	3.8×10^{-4}	1.5×10^{-7}	(e)	(e)
10. 7.6-meter drop of transfer basket in ATS-16 BWR fuel assemblies-no filtration	1.9×10^{-7}	2.2×10^{-3}	1.1×10^{-6}	5.1×10^{-1}	2.6×10^{-4}	5.1×10^{-1}	2.0×10^{-4}	(e)	(e)
11. 6-meter drop of disposal container in DCHS-21 PWR assemblies-filtration	1.8×10^{-3}	7.3×10^{-6}	3.7×10^{-9}	8.6×10^{-2}	4.3×10^{-5}	1.3×10^{-3}	5.2×10^{-7}	(e)	(e)
12. 6-meter drop of disposal container in DCHS-21 PWR fuel assemblies-no filtration	8.6×10^{-7}	6.1×10^{-3}	3.1×10^{-6}	1.6	8.0×10^{-4}	1.3	5.2×10^{-4}	(e)	(e)
13. Transporter runaway and derailment in access tunnel-21 PWR assemblies-filtration-16-meter drop height equivalent	1.2×10^{-7}	1.3×10^{-2}	6.5×10^{-6}	3.2	1.6×10^{-3}	3.9	1.6×10^{-3}	(f)	(f)
14. Earthquake - 375 PWR assemblies	2.0×10^{-5}	3.2×10^{-2}	1.6×10^{-5}	14	7.2×10^{-3}	7.0	2.8×10^{-2}	(f)	(f)
15. Earthquake w/fire in WTB	2.0×10^{-4}	5.8×10^{-5}	2.9×10^{-8}	2.1	1.1×10^{-5}	5.2×10^{-3}	2.1×10^{-6}	(f)	(f)
16. LLW drum rupture in WTB	0.59	1.9×10^{-9}	9.5×10^{-13}	7.5×10^{-7}	3.7×10^{-10}	1.4×10^{-7}	5.6×10^{-11}	7.0×10^{-5}	2.8×10^{-8}

a. Source: Appendix H.

b. CTHA = Cask Transfer/Handling Area, CTS = Canister Transfer System, ATS = Assembly Transfer System, DCHS = Disposal Container Handling System, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. LCFi is the likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers probable in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection, as discussed in this section.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident since operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on current staffing projections (TRW 1998i, pages 17 and 18).

these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

The most severe accident scenario (earthquake, Table 4-36, number 14) for the 95-percent weather conditions would result in an estimated 0.0072 additional latent cancer fatality for the same affected population. The more conservative summation of all potential accidents in Table 4-36 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the individual receptors from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. As noted in Chapter 2, this EIS evaluates other packaging scenarios that include commercial spent nuclear fuel that would arrive at the repository in canisters suitable for disposal without being opened. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, thus provides a bounding assessment of accident impacts for the packaging scenarios considered in Chapter 2 because accident scenarios involving damage to bare fuel assemblies during handling operations represent the bounding repository accident scenarios. The uncanistered fuel, as indicated in Tables 4-35 and 4-36, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.

The analysis evaluated accident scenario impacts during retrieval, and concluded that the transporter runaway and derailment accident scenarios evaluated for emplacement operation would bound other accident scenarios during retrieval operations that are credible. This conclusion is supported by the results of accident evaluations for above-ground dry storage at utility sites, as discussed in Appendix H.

4.1.8.2 Nonradiological Accidents

A potential release of hazardous or toxic materials during postulated operational accidents involving spent nuclear fuel or high-level radioactive waste at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act. Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a vitrified glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals (see Section 4.1.3.2). These substances are in common use at other DOE sites. Section 4.1.7 describes potential impacts to workers from normal industrial hazards in the workplace (which includes industrial accidents). The statistics used in the analysis were derived from DOE accident experience at other sites. Impacts to members of the public would be unlikely because the chemicals would be mostly liquid and solid so that any release would be confined locally. (For example, chlorine at the site used for water treatment would be in powder form, so a gaseous release of chlorine would not be possible. Propane gas would not be stored at the site.)

Section 4.1.12.2 describes the quantities of solid hazardous waste generated during repository operations. The construction and closure phases would not generate liquid hazardous waste. The generation, storage, and shipment off the site of solid and liquid hazardous waste generated during operations would represent minimal incremental risk from accidents. Impacts to workers from industrial accidents in the workplace are part of the statistics presented in Appendix F, Section F.2.

4.1.8.3 Sabotage

The accident analysis separately considered sabotage as a potential initiating event. This event would be unlikely to contribute to impacts from the repository. The repository would not represent an attractive target to potential saboteurs due to its remote location and the low population density in the area. Furthermore, security measures DOE would use to protect the waste material from intrusion and sabotage (TRW 1999a, pages 63 to 65) would make such attempts unlikely to succeed. At all times the waste material would be either in robust shipping or disposal containers or inside the Waste Handling Building, which would have thick concrete walls. On the basis of these considerations, DOE concluded that sabotage events would be unlikely at the repository.

4.1.9 NOISE IMPACTS

This section describes possible noise impacts to the public (nuisance noise) and workers (occupational noise) from performance confirmation, construction, operation and monitoring, and closure activities. Repository areas that could generate elevated noise levels include the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas. The following discussion identifies potential impacts that primarily would affect workers during routine operations. Overall, however, the potential for noise impacts to the public would be very small due to the distances of residences from these areas. Section 4.1.4.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Performance Confirmation

As part of site characterization, DOE has evaluated existing noise conditions in the Yucca Mountain region. The noise associated with site characterization activities, which has included that from construction, equipment, drilling equipment, and occasional blasting, has not resulted in large impacts. Because performance confirmation activities would be similar to those for site characterization, large impacts would be likely.

4.1.9.2 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise in the analyzed land withdrawal area during the construction phase would include activities at the North Portal, South Portal, and Ventilation Shaft Operations Areas involving heavy equipment (bulldozers, graders, loaders, pavers, etc.), cranes, ventilation fans, and diesel generators. Sources of noise during the operation and monitoring phase would include transformer noise, compressors, ventilation fans, air conditioners, and a concrete batch plant. Ventilation fans would have silencers that would keep noise levels below 85 dBA (see Chapter 3, Section 3.1.9 for an explanation of noise measurements) at a distance of 3 meters (10 feet) (TRW 1997c, page 107). The Occupational Safety and Health Administration has identified that the maximum permissible continuous noise level that workers may be exposed to without controls is 90 dBA [29 CFR 1910.95(b)(2)].

The distance from the North Portal Operations Area to the nearest point on the boundary of the analyzed land withdrawal area analyzed would be about 11 kilometers (7 miles) due west. The distance from the South Portal Operations Area to the nearest point on the land withdrawal area boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) (DOE 1997k, all).

To establish the propagation distance of repository-generated noise for analysis purposes, DOE used an estimated maximum sound level [132 decibels, A-weighted (dBA) for heavy construction equipment, although heavy trucks generate sound levels of between 70 and 80 dBA at 15 meters (50 feet)]. An analysis determined the distance at which that noise would be at the lower limit of human hearing (20 dBA). The calculated distance was 6 kilometers (3.7 miles). Thus, noise impacts would be unlikely at the analyzed land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical receptor at the analyzed land area withdrawal boundary would be large enough to reduce the noise to background levels and because there would be no residential or community receptors at the withdrawal area boundary [the nearest housing is in Lathrop Wells, about 22 kilometers (14 miles) from the repository site], DOE expects no large noise impacts to the public from repository construction and operations.

Workers at the repository site could be exposed to elevated levels of noise. Small impacts such as speech interference between workers and annoyance to workers would occur. However, worker exposures during all repository phases would be controlled such that impacts (such as loss of hearing) would be unlikely. Engineering controls would be the primary method of noise control. Hearing protection would be required, as needed, as a supplement to engineering controls.

Noise impacts associated with closure would be similar to those associated with construction and operations. Therefore, DOE expects no large noise impacts to the public and workers.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from performance confirmation, construction, operation and monitoring, and closure activities. These activities would not cause adverse impacts to aesthetic or visual resources in the region. The analysis of such impacts considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The analysis gave specific consideration to scenic quality, visual sensitivity, and distance from observation points.

Yucca Mountain has visual characteristics fairly common to the region (a scenic quality rating of C), and the visibility of the repository site from publicly accessible locations is low or nonexistent. The largest structure would be the Waste Handling Building at the North Portal Operations Area, which would be about 37 meters (120 feet) tall with a taller exhaust stack. Other buildings and structures would be smaller and at elevations equal to or lower than that of the Waste Handling Building. No building or structure would exceed the elevation of the southern ridge of Yucca Mountain [1,400 meters (4,600 feet)]. Therefore, no part of the repository would be visible to the public from the west. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near Lathrop Wells and the Amargosa Valley, approximately 28 kilometers (17 miles) away. There is no public access to the north or east of the site to enable viewing of the facilities. DOE would provide lighting for operation areas at the repository. This lighting could be visible from public access points.

Closure activities, such as dismantling facilities and reclaiming the site, probably would improve the visual quality of the landscape. Adverse impacts to the visual quality due to closure would be unlikely.

4.1.11 IMPACTS TO UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to residential water, energy, materials, and site services from performance confirmation, construction, operation and monitoring, and closure activities. The scope of the analysis included electric power use, fossil-fuel consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. The analysis compared needs to available capacity. The region of influence would include the local, regional, and national supply infrastructure that would have to satisfy the needs. The analysis used engineering estimates of requirements for construction materials, utilities, and energy.

Construction activities would occur during both the construction and the operation and monitoring phases. Table 4-37 lists electric energy and fossil-fuel use during the different phases. Table 4-38 lists construction material use. Both tables list comparative values for all thermal load and packaging scenarios. DOE prorated impacts to site services, if any, with those to the commodity areas to produce an estimate of overall impacts.

Overall, DOE does not expect meaningful impacts to residential water, energy, materials, and site services from the Proposed Action. DOE would, however, have to enhance the electric power delivery system to the Yucca Mountain site.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Performance Confirmation

DOE would obtain utilities, energy, and materials for performance confirmation activities from existing sources and suppliers. Water would come from existing wells. Power would come from regional suppliers to the existing Nevada Test Site transmission system. Based on site characterization activities, performance confirmation activities would not cause meaningful impacts to regional utility, energy, and material sources. In addition, DOE would continue to use such existing site services as emergency medical support, fire protection, and security and law enforcement (as described in Chapter 3, Section 3.1.11.3) during performance confirmation.

4.1.11.2 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operation and Monitoring, and Closure

Residential Water

Population growth associated with the Proposed Action could affect regional water resources. Based on the information in Section 4.1.6, in 2030 the Proposed Action would result in a maximum population increase of about 3,700 in Clark and Nye Counties. About 80 percent of these people would live in Clark County and about 20 percent in Nye County. Whether domestic water needs were satisfied predominantly from surface-water sources, as is the case for most of Clark County, or from groundwater sources, as for most of Nye County, these relatively small increases in population would have very minor impacts on existing water demands.

The maximum project-related population increase for Clark County would amount to about 0.3 percent of the 1997 population (see Chapter 3, Section 3.1.7.1). This increase would be a smaller portion of the county's population in 2030 and, correspondingly, the associated increase in water demand in the county as a result of the proposed project would be very small. The population of Indian Springs in Clark

Table 4-37. Electricity and fossil-fuel use for the Proposed Action.[a]

Phase[b]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Peak electrical power demand (megawatts)										
Construction	2005-2010	24	24	24	24	24	24	24	24	24
Operation and monitoring	2010-2110									
Development	2010-2032	19	19	19	19	19	19	19	19	19
Emplacement	2010-2033	22	18	19	22	18	19	22	18	19
Total development and emplacement	*2010-2033*	*41*	*38*	*38*	*41*	*38*	*38*	*41*	*38*	*38*
Decontamination	2034-2037	14	10	11	14	10	11	14	10	11
Monitoring	2034-2110	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2060	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2310	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Closure	2110+6-15	9.2	8.9	8.9	9.2	8.9	8.9	9.2	8.9	8.9
Electricity use (1,000 megawatt-hours)										
Construction	2005-2010	180	180	180	230	230	230	240	240	240
Operation and monitoring	2010-2110									
Development	2010-2032	650	650	650	890	890	890	2,200	2,200	2,200
Emplacement	2010-2033	2,600	2,100	2,100	2,600	2,100	2,100	2,600	2,100	2,200
Decontamination	2034-2037	250	190	200	250	190	200	250	190	200
Monitoring	2034-2110	2,000	2,000	2,000	2,400	2,400	2,400	3,500	3,500	3,500
	2034-2060	680	680	680	810	810	810	1,200	1,200	1,200
	2034-2310	7,200	7,200	7,200	8,600	8,600	8,600	13,000	13,000	13,000
Total 100-year phase	*2010-2110*	*5,500*	*4,900*	*5,000*	*6,100*	*5,600*	*5,600*	*8,600*	*8,000*	*8,100*
Closure	2110+6-15	250	240	240	370	370	370	560	560	560
Fossil-fuel use (million liters)[f]										
Construction	2005-2010	8.1	7.1	7.3	12	11	12	14	13	13
Operation and monitoring	2010-2110									
Development	2010-2032	19	19	19	20	20	20	83	83	85
Emplacement	2010-2033	230	180	190	230	180	190	230	180	190
Decontamination	2034-2037	33	26	27	33	26	27	33	26	27
Monitoring	2034-2110	11	11	11	15	15	15	15	15	15
	2034-2060	3.9	3.9	3.9	5.0	5.0	5.0	5.0	5.0	5.0
	2034-2310	41	41	41	53	53	53	53	53	53
Total 100-year phase	*2010-2110*	*290*	*240*	*240*	*290*	*250*	*250*	*360*	*310*	*310*
Closure	2110+6-15	5.1	4.5	4.6	9.4	8.8	8.9	15	14	15

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-17 to 6-24).
b. Approximate periods for each phase would be construction, 5 years; operation and monitoring, 100 years; closure, 6-15 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. To convert liters to gallons, multiply by 0.26418.

Table 4-38. Construction material use for the Proposed Action.[a]

Phase[b]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Concrete (1,000 cubic meters)[f]										
Construction	2005-2010	330	330	330	390	380	380	390	390	390
Operation and monitoring	2010-2110									
Development	2010-2032	420	420	420	480	480	480	1,700	1,700	1,700
Emplacement	2010-2033	27	27	27	27	27	27	66	66	66
Operation and monitoring total	*2010-2110*	*450*	*450*	*450*	*510*	*510*	*510*	*1,800*	*1,800*	*1,800*
Closure	2110+6-15	2	2	2	2	2	2	4	4	4
Project total		*780*	*780*	*780*	*900*	*890*	*890*	*2,200*	*2,200*	*2,200*
Steel (1,000 metric tons)[g]										
Construction	2005-2010	70	68	67	81	81	81	83	81	80
Operation and monitoring	2010-2034									
Development	2010-2032	90	90	90	140	140	140	610	610	610
Emplacement	2010-2033	42	42	42	42	42	42	110	110	110
Operation and monitoring total	*2010-2110*	*130*	*130*	*130*	*180*	*180*	*180*	*720*	*720*	*720*
Closure	2110+6-15	0.71	0.71	0.71	0.92	0.92	0.92	2	2	2
Project total		*200*	*200*	*200*	*260*	*260*	*260*	*800*	*800*	*800*
Copper (1,000 metric tons)										
Construction	2005-2010	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operation and monitoring	2010-2110									
Development	2010-2032	0.1	0.1	0.1	0.1	0.1	0.1	0.9	0.9	0.9
Project total		*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*1.0*	*1.0*	*1.0*

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-15 to 6-21).
b. Approximate periods for each phase would be construction, 5 years; operation and monitoring, 100 years; closure, 6-15 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. To convert cubic meters to cubic yards, multiply by 1.3079.
g. To convert metric tons to tons, multiply by 1.1023

County would increase by a projected maximum of about 110 as a result of the Proposed Action. This number represents about 10 percent of the 1997 Indian Springs population and, based on a Las Vegas Valley average demand for domestic water of 720 liters (190 gallons) per day per person (SNWA 1999, all), would require a quantity of water that is about 6 percent of the community's quasimunicipal groundwater withdrawal in 1997 [0.51 million cubic meters (410 acre-feet)] (NDCNR 1998, all). DOE expects the population of Indian Springs to be larger by 2030 and on a percentage basis, the contribution (and associated water demand) from project-related growth would be smaller than current numbers. However, this small community would be more likely to be affected by projected growth than other areas in Clark County.

In Nye County, estimates of domestic water demand for 1995 are about 750 liters (200 gallons) per day per person (Horton 1997, Table 10). At this demand, the project-related increase in Nye County population would result in an additional water demand of about 0.20 million cubic meters (160 acre-feet) of water per year. This represents about 0.2 percent of the water use in Nye County in 1995. As indicated in Section 4.1.6, most (about 92 percent) of the project-related growth in Nye County would occur in Pahrump. This would equate to adding about 0.18 million cubic meters (150 acre-feet) to Pahrump's annual water demand, which represents about 0.6 percent of the 1995 Pahrump water withdrawal of 30 million cubic meters (24,000 acre-feet). By 2030, when the peak population increases would occur, the project-related increase in water demand would be an even smaller percentage of the total Nye County and Pahrump water need. The increase in domestic water demand in Nye County as a result of the proposed project would be very small.

Residential Sewer

Sewer utilities could be affected by population growth associated with the Proposed Action. In Clark County, where most of the population growth would take place, the fact that the maximum project-related population increase would amount to about 0.3 percent of the 1997 population indicates that impacts to the populous areas of the county (that is, the Las Vegas Valley) would be very small. In Indian Springs, where project-related growth would be a more substantial portion of the community population, small treatment facilities designed for a specific area or individual household septic tank systems would accommodate wastewater treatment needs. In either case, the added population would not be likely to cause overloading to a sewer utility.

Growth in Nye Country from the Proposed Action would be likely to occur primarily in the Pahrump area. There is no reason to believe that project-related population increases would overload a sewer utility. Again, small, limited-service treatment facilities or individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

Electric Power

During the construction phase (2005 to 2010), the demand for electricity would increase as DOE operated two or three tunnel boring machines and other electrically powered equipment. The tunnel boring machines would account for more than half of the demand for electricity during the construction phase. The estimated peak demand for electrical power during the construction phase would be about 24 megawatts with use varying between about 180,000 and 240,000 megawatt-hours, depending on the thermal load scenario and the packaging scenario. Excavation activities for all three thermal load scenarios would use two or three tunnel boring machines. However, the operations time would increase for the low thermal load scenario because of the increased tunnel lengths.

As discussed in Chapter 3, Section 3.1.11.2, the current electric power supply line has a peak capacity of only 10 megawatts. DOE, therefore, is evaluating modifications and upgrades to the site electrical system, as discussed below.

During the early stages of the operation and monitoring phase (2010 to 2033), the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be between 38 and 41 megawatts, depending on the thermal load scenario and the packaging scenario.

Following the completion of excavation activities in about 2032, the demand for electric power would drop to about 20 megawatts and would continue to drop, following the completion of emplacement and decontamination activities in about 2037, to less than 15 megawatts for monitoring and maintenance activities. The closure phase would last from 6 to 15 years, depending on the thermal load scenario. The peak electric power demand would be less than 10 megawatts for any of the three thermal load scenarios during closure.

The repository demand for electricity would be well within the expected regional capacity for power generation. Nevada Power Company, for example, experienced a growth in peak demand of nearly 30 percent from 1993 to 1997 and has demonstrated the ability to meet customer demand in this high-growth environment through effective planning (*Las Vegas Review-Journal* 1998, all). Nevada Power's current planning indicates that it intends to maintain a reserve capacity of 12 percent. In 2010, at the beginning of the operation and monitoring phase, Nevada Power projects a net peak load of 5,950 megawatts and is planning a reserve of 714 megawatts (NPC 1997, Figures 2 and 4). The maximum 41-megawatt demand that the repository would require would be less than 1 percent of the projected peak demand in 2010, and less than 6 percent of the planned reserve. Thus, DOE expects that regional capacity planning would accommodate the future repository demand.

Repository Electric Power Supply Options

As discussed above, the estimated repository electric power demand would exceed the current electric supply capacity to the site after construction began in 2005. DOE would have to increase the electric power supply to the site to accommodate the initial demand of about 24 megawatts during the construction phase and to support the estimated peak demand of as much as 41 megawatts during the operation and monitoring phase. A range of options focusing on a modification or upgrade of the existing transmission and distribution system is under consideration to meet the repository electricity demand (TRW 1998e, all). DOE eliminated consideration of onsite generation of electricity in conjunction with the onsite plant that would generate steam for heating because the steam plant would be much smaller than a plant needed for power generation, and increasing the capacity of the steam plant would not be cost-effective with the availability of low-priced power in the southern Nevada region. Limited onsite generation capacity would use diesel-powered generators for emergency equipment.

As discussed in Chapter 3, Section 3.1.11.2, the repository site receives electricity through a feeder line from the Canyon Substation, which is rated at 69 kilovolts and has a capacity of 10 megawatts. The minimum modification would be to upgrade this line to 40 to 50 megawatts, modify the Nevada Test Site power loop to support repository operations in conjunction with other Test Site activities, and upgrade utility feeder lines to the Nevada Test Site. The existing Nevada Test Site power loop has a rated capacity of about 72 megawatts, but preliminary analysis of loop performance with the projected repository load (as much as 41 megawatts) indicated that unacceptable voltage reductions could occur at some Test Site locations. The minimum modification to the power loop to reduce the potential for unacceptable voltage reductions would be to install capacitors in the loop. Other options to obtain satisfactory performance for the power loop would include upgrading sections of the loop and the utility-owned feeder lines to the loop. Additional options, which would be variations of this approach, would include providing upgraded power lines directly from the utilities to the repository site.

As discussed in Chapter 3, Section 3.1.11.2, two commercial utility companies supply electricity to the Nevada Test Site feeder lines that power the Test Site power loop. Nevada Power Company owns and operates a 138-kilovolt line from the Las Vegas area to the Mercury Switching Station on the Test Site. Valley Electric Association owns and operates 138- and 230-kilovolt lines from the Las Vegas area to Pahrump and a 138-kilovolt line from Pahrump to the Jackass Flats substation on the Test Site near Lathrop Wells. The options DOE is evaluating include upgrading either or both of these lines. The options also include connecting both utility feeder lines directly to the repository with new 138- or 230-kilovolt lines to either the North or South Portal to obtain independent redundant power capability. DOE has considered adding Sierra Pacific Power Corporation as a supplier by constructing a new power line from the Tonopah/Anaconda area to Lathrop Wells through Beatty with a direct tie to the South Portal at the repository. All system modifications would include appropriate modifications to transformers and switchgear. The approach in all cases would be to use existing power corridors where possible to limit environmental impacts and to reduce the need for additional rights-of-way. Depending on the option chosen, additional National Environmental Policy Act analysis could be required.

Fossil Fuels

Fossil fuels used during the construction phase (2005 to 2010) would include diesel fuel and fuel oil. Diesel fuel would be used primarily to operate surface construction equipment and equipment to maintain the excavated rock pile. Fuel oil would fire a steam plant at the North Portal, which would provide building and process heat for the North Portal Operations Area. In addition, fuel oil would provide water heating and building heat to the South Portal and heat for curing precast concrete components. During construction the estimated use of diesel fuel and fuel oil would be 7.1 million to 14 million liters (1.9 million to 4 million gallons). The highest use would be associated with the combination of the low thermal load scenario and the uncanistered packaging scenario. The regional supply capacity of gasoline and diesel fuel is about 3.8 billion liters (1 billion gallons) per year for the State of Nevada, based on motor fuel use (BTS 1999a, all). About half of the State total is consumed in the three-county region of influence (Clark, Lincoln, and Nye Counties) with the highest consumption in Clark County, so yearly repository use during the construction phase would be less than 1 percent of the current regional consumption.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It would range between about 240 million and 360 million liters (about 63 million and 95 million gallons) depending on the thermal load scenario and the packaging scenario. The annual use would be highest for emplacement and development operations (2010 to 2033) and would decrease substantially for monitoring and maintenance activities (2034 to 2110). The projected use of liquid fossil fuels would be within the regional supply capacity and should not cause meaningful impacts. As discussed above, motor fuel use in the State of Nevada in 1996 was about 3.8 billion liters (1 billion gallons) (BTS 1999a, all), which provides the baseline for the regional supply capacity. The highest annual use during the operations and monitoring phase would be less than 5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties.

During the closure phase, fossil-fuel use would be between 4.5 million and 15 million liters (1.2 million and 4 million gallons), depending on the thermal load scenario. Use during the closure phase would be similar to that for the construction phase.

Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for tunnel liners in the subsurface and for the construction of the surface facilities. Excavated rock would be used for the aggregate, and cement would be purchased regionally. During the construction phase the amount of concrete required would range from about 330,000 to 390,000 cubic meters (about 430,000 to 510,000 cubic yards), depending on the thermal load scenario and the packaging scenario. For this phase, as much as about 83,000 metric tons (92,000 tons) of steel would be required for a variety of uses including rebar, piping, vent ducts, and track, and 100 metric tons (110 tons) of copper for electrical cables. Because the subsurface configuration of the repository would differ substantially for the high, intermediate, and low thermal load scenarios, the relative amount of material used during the initial 5-year construction period might not be indicative of the amount required to complete the subsurface through the end of development. For example, the amount of steel used during the construction phase for each of the intermediate thermal load cases would be about the same as the amount for the corresponding low thermal load case, but the total amount of steel used for each intermediate case through the completion of development would be about one-quarter of the amount that would be used for the corresponding low thermal load case.

During the operation and monitoring phase, an additional 1.8 million cubic meters (2.4 million cubic yards) of concrete would be required for the low thermal load scenario and 450,000 cubic meters (590,000 cubic yards) would be required for the high thermal load scenario. The corresponding requirement for steel would be between about 720,000 and 130,000 metric tons (about 790,000 and 140,000 tons), and for copper it would be about 100 metric tons (110 tons).

For the low thermal load scenario, which would require the most concrete, the average yearly concrete demand for continued subsurface development during the operation and monitoring phase would be about 82,000 cubic meters (about 110,000 cubic yards). This quantity of concrete represents less than 3 percent of the cement consumed in Nevada in 1998 (Sherwood 1998, all).

Because the markets for steel and copper are worldwide in scope, DOE expects little or no impact from increased demand for steel and copper in the region.

The closure phase would require an estimated maximum of 4,000 cubic meters (5,200 cubic yards) of concrete for the low thermal load option. An estimated 2,000 metric tons (2,200 tons) of steel would be required for the low thermal load scenario and about 710 metric tons (780 tons) for the high thermal load scenario.

Site Services

During the construction phase, DOE would rely on the existing support infrastructure described in Chapter 3, Section 3.1.11.3, during an emergency at the repository. DOE would maintain these capabilities until the project could provide its own services on the site.

The primary onsite response would occur through the onsite Fire Station, Medical Center, and Health Physics facilities after their construction at the North Portal was complete. The Fire Station would maintain fire and rescue vehicles, equipment, and trained professionals to respond to fires, including radiological, mining, industrial, and accident events at the surface and subsurface. The Medical Center would be adjacent to the Fire Station, and would maintain a full-time doctor and nurse and medical supplies to treat emergency injuries and illnesses. These facilities would have the capability to provide complete response to most onsite emergencies. DOE would coordinate the operation of these facilities with facilities at the Nevada Test Site and in the surrounding area to increase response capability, if necessary.

A site security and safeguards system would include the surveillance and safeguards functions required to protect the repository from unauthorized intrusion and sabotage. The system would include the site security barriers, gates, and badging and automated surveillance systems operated by trained security officers. Support for repository security would be available from the Nevada Test Site security force and the Nye County Sheriff's Department, if needed.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities should be able to respond to and mitigate most onsite incidents, including underground incidents, without outside support. Therefore, no meaningful impact to the emergency facilities of surrounding communities or counties would be likely.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of the radioactive and nonradioactive waste that DOE would generate as a result of performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that repository-related activities would generate. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes. The overall impact of managing the Yucca Mountain repository waste streams would not differ among the thermal load scenarios and packaging scenarios. DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater. The Proposed Action would not cause meaningful impacts at offsite facilities for low-level radioactive and hazardous waste disposal. DOE would use less than 3 percent of the existing offsite capacity for low-level radioactive waste disposal and a very small fraction of the existing hazardous waste disposal capacity. In addition, the Department would build an onsite landfill. Although such activities are not currently planned, the use of existing Nevada Test Site landfills for the disposal of construction and demolition debris and sanitary and industrial solid waste would require the continuation of the operation of these facilities past their estimated lives of 70 and 100 years (DOE 1995f, pages 8 and 9) and probably would require the expansion of their capacities. Further review under the National Environmental Policy Act might be required to expand the capacity of the landfills at the Nevada Test Site.

4.1.12.1 Waste and Materials Impacts from Performance Confirmation

DOE expects performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal qualities (TRW 1999a, page 17). Based on 1997 waste generation reports, performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (Sygitowicz 1998, pages 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (Harris 1998, pages 3-6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

DOE would use current (as described in Chapter 3, Section 3.1.12) or similar methods to handle the waste streams generated by its performance confirmation activities. It would also use offsite landfills to dispose of solid waste and construction debris; accumulate and consolidate hazardous waste and transport it off the site for treatment and disposal; treat and reuse wastewater; and treat and dispose of

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

sanitary sewage. Based on site characterization experience, performance confirmation activities would cause no meaningful impacts to the regional waste disposal capacity.

4.1.12.2 Waste and Materials Impacts from Construction, Operation and Monitoring, and Closure

The construction phase (2005 to 2010) would generate nonhazardous, nonradioactive wastes and some hazardous waste from the use of such materials as resins, paints, and solvents. Nonhazardous, nonradioactive wastes would include sanitary and industrial solid wastes, construction debris, industrial wastewater, and sanitary sewage. Table 4-39 lists the estimated quantities of waste that the construction phase would generate. These estimates are based on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from dust suppression.

DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. However, as part of the Proposed Action, DOE would construct a State-permitted landfill on the Yucca Mountain site to dispose of nonrecyclable construction debris and

Table 4-39. Estimated waste quantities from construction.[a]

Waste type	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Construction debris (cubic meters)[e]	3,000	2,400	2,400	3,000	2,400	2,400	3,000	2,400	2,400
Hazardous (cubic meters)	990	690	740	990	690	740	990	690	740
Sanitary and industrial solid (cubic meters)	10,000	8,500	8,700	10,000	8,500	8,700	10,000	8,500	8,700
Sanitary sewage (million liters)[f]	160	150	150	160	160	160	160	160	160
Industrial wastewater (million liters)	42	42	42	51	51	51	51	51	51

a. Sources: TRW (1999a, page 66); TRW (1999b, pages 6-8 and 6-9).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

sanitary and industrial solid waste. The capacity of this landfill would be large enough to dispose of the projected volumes of this debris and waste for the entire Proposed Action. As listed in Table 4-39, DOE estimates a maximum of 3,000 cubic meters (110,000 cubic feet) of construction debris. If the Department chose not to build a landfill at the repository site, it could ship construction debris to the Test Site's Area 10C landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996f, page 4-37). The disposal of construction debris generated during the construction phase would consume less than one-half of 1 percent of the disposal capacity in this landfill. DOE could also ship repository-generated sanitary and industrial solid waste to the Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996f, page 4-37). The disposal of the maximum of 10,000 cubic meters (350,000 cubic feet) of sanitary and industrial solid waste generated during the construction phase at the Area 23 landfill would use about 2 percent of the disposal capacity.

Table 4-40 lists the estimated total waste quantities for repository activities associated with emplacement and development (2010 to 2033). Major waste-generating activities would include the receipt and packaging of spent nuclear fuel and high-level radioactive waste and continued development of subsurface emplacement areas. The thermal load scenarios would cause differences in nonradioactive waste quantities from subsurface activities due to the different workforce sizes and main drift lengths. The three packaging scenarios would affect the volumes of hazardous and low-level radioactive wastes generated at the surface facilities as a result of differences in handling the spent nuclear fuel and high-level radioactive waste. In addition, waste would be generated in personnel areas such as change rooms, restrooms, and offices. The dual-purpose canister packaging scenario could require the disposal of an additional estimated 44,000 cubic meters (1.6 million cubic feet) of low-level radioactive waste (not listed in Table 4-40) with an estimated weight of 240,000 metric tons (270,000 tons) (Koppenaal 1998a, all; TRW 1999a, page 75). DOE could decide to recycle the canisters if doing so would be more protective of the environment and more cost effective than direct disposal. Recycling would require melting and recasting of the canister metal to enable other uses.

DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department could continue to dispose of such waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or could contract separately with the same or another commercial facility. As listed in Table 4-39, DOE estimates the generation of no more than 990 cubic meters (35,000 cubic feet)

Table 4-40. Estimated waste quantities from emplacement and development activities (2010 to 2033).[a]

Waste type	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Hazardous (cubic meters)[e]	5,800	2,300	2,200	5,800	2,300	2,200	5,800	2,300	2,200
Sanitary and industrial solid (cubic meters)	50,000	41,000	42,000	50,000	41,000	42,000	70,000	61,000	62,000
Sanitary sewage (million liters)[f]	1,400	1,100	1,200	1,400	1,100	1,100	1,400	1,200	1,200
Industrial wastewater (million liters)	900	780	780	930	810	810	1,400	1,300	1,300
Low-level radioactive (cubic meters, after treatment)	67,000	18,000	26,000	67,000	18,000	26,000	67,000	18,000	26,000

a. Sources: TRW (1999a, pages 75 and 76); TRW (1999b, pages 6-17, 6-18, and 6-23).
b. UC = uncanistered.
c. DISP = disposable canister.
d. DPC = dual-purpose canister.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

of hazardous waste during the construction phase. This maximum volume would result from the construction of facilities to accommodate the uncanistered packaging scenario. The Environmental Protection Agency's National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 1993 to 2013 capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states (including Nevada and other states to which repository waste could be shipped for treatment and disposal) is about seven times more than the demand for these services. The landfill capacity would be about 50 times the demand. Therefore, the impact to capacity from the treatment and disposal of hazardous waste from the construction phase would be very small.

DOE would treat and dispose of sanitary sewage and industrial wastewater at onsite facilities. Sanitary sewage from the North Portal Operations Area would go to an existing septic system. The Department would install another septic system to dispose of sanitary sewage from the South Portal Operations Area. The industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal Operations Area and wastewater from the subsurface would flow to an evaporation pond at the South Portal Operations Area. Sludge would accumulate in the North Portal Operations Area evaporation pond so slowly that DOE would not need to remove it before the closure of the pond (TRW 1998g, pages 65 to 67). The accumulated sludge at the South Portal Operations Area evaporation pond, which would consist of mined rock, Portland Cement, and fine aggregate, would be removed as needed and added to the excavated rock pile (Koppenaal 1998b, page 3).

During the operation and monitoring phase (2010 to 2110), the receipt and packaging of spent nuclear fuel and high-level radioactive waste, the operation of support facilities, and the continued development of subsurface emplacement areas would generate radioactive and nonradioactive wastes and wastewaters and some hazardous waste. DOE does not expect to generate mixed waste. However, repository facilities would also have the capability to package and temporarily store mixed waste that operations could generate in unusual circumstances. In addition, the medical clinic would generate a small amount of medical waste that would be disposed of in accordance with applicable Federal and State of Nevada requirements.

Monitoring and maintenance activities after the completion of emplacement (2034 to 2110) would also generate wastes, but in much smaller quantities. The first few years after the completion of emplacement would generate greater quantities of waste due to the decontamination and decommissioning of surface nuclear facilities. DOE estimates as much as 520 cubic meters (18,000 cubic feet) of low-level radioactive waste and as much as 260 cubic meters (9,200 cubic feet) of hazardous waste from this activity (TRW 1999a, page 78), depending on the packaging scenario.

Monitoring and maintenance activities over 26 years would generate a maximum of about 9,900 cubic meters (350,000 cubic feet) of sanitary and industrial solid waste and about 230 million liters (60 million gallons) of sanitary sewage. Ongoing monitoring and maintenance activities for 76 years would generate a maximum of about 20,000 cubic meters (710,000 cubic feet) of sanitary and industrial solid waste and about 450 million liters (120 million gallons) of sanitary sewage. Ongoing monitoring and maintenance activities for 276 years (closure 300 years after the start of emplacement) would generate a maximum of about 61,000 cubic meters (about 2.2 million cubic feet) of sanitary and industrial solid waste and about 1.3 billion liters (340 million gallons) of sanitary sewage (TRW 1999a, page 85; TRW 1999b, pages 6-28 and 6-29).

During the operation and monitoring phase DOE would dispose of sanitary sewage and industrial wastewater in the onsite wastewater systems and sanitary and industrial solid waste in the onsite landfill or at the Nevada Test Site. The sanitary sewage disposal system would be able to handle the estimated daily sewage flows, and the industrial wastewater facilities would be able to handle the estimated annual wastewater flows. DOE would use the onsite landfill to dispose of sanitary and industrial solid waste, or it could use the existing Nevada Test Site landfill in Area 23 to dispose of such waste. The Area 23 landfill has an estimated 100-year capacity for the disposal of waste generated at the Test Site (DOE 1995f, page 9); the addition of repository-generated waste during the operation and monitoring phase would necessitate its expansion.

DOE would treat low-level radioactive waste in the Waste Treatment Building (see Section 2.1.2.1). After treatment, DOE would need to dispose of an estimated maximum 68,000 cubic meters (2.4 million cubic feet) of low-level radioactive waste generated during emplacement activities and the decontamination of surface nuclear facilities (TRW 1999a, pages 72 and 78). This waste would be disposed of at the Nevada Test Site. The Test Site accepts low-level radioactive waste for disposal from other DOE sites. It has an estimated disposal capacity of 3.15 million cubic meters (110 million cubic feet) (DOE 1998l, page 2-19) (see Section 3.1.12). The impact to the total capacity at the Nevada Test Site from the disposal of repository low-level radioactive waste would be 2.2 percent.

During the operation and monitoring phase repository-generated hazardous waste would be shipped off the site for treatment and disposal in a permitted facility. DOE would need to dispose of an estimated maximum of 6,100 cubic meters (220,000 cubic feet) of hazardous waste generated by emplacement activities and the decontamination of surface facilities (TRW 1999a, pages 72 and 78). The estimated maximum annual rate of hazardous waste treatment or disposal would be 260 cubic meters (9,200 cubic feet) (TRW 1999a, page 78). At present, a number of commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 20-year available capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states is about seven times more than the demand for these services. The estimated landfill capacity is about 50 times the demand. Therefore, the impact to capacity from the treatment and disposal of repository-generated hazardous waste during the operation and monitoring phase would be very small.

If unusual activities generated mixed waste, DOE would package such waste for offsite treatment and disposal. The estimated maximum annual quantity would be about 1 cubic meter (35 cubic feet) (TRW 1999a, page 74), which would have a very small impact on the receiving facility. At present, there is commercial capacity (for example, at Envirocare of Utah, with which the Department has a contract for the treatment and disposal of mixed waste). DOE is also pursuing a permit for a mixed waste disposal facility at the Nevada Test Site that would accept mixed waste from other DOE sites for disposal (DOE 1996f, page 4-36). This facility has a planned annual capacity of 13,000 cubic meters (460,000 cubic feet) (DOE 1997b, Volume 1, page 6-6).

Closure activities, such as the final decontamination and demolition of the repository structures and the restoration of the site, would generate waste and recyclable materials. Table 4-41 lists estimated waste quantities for the closure phase. The ranges of quantities result from more waste generated from more years to complete closure with the low thermal load scenario and differences in surface facilities for the packaging scenarios.

Table 4-41. Estimated waste quantities from closure.[a]

Waste type	Quantity
Demolition debris (cubic meters)[b]	100,000 - 150,000
Hazardous (cubic meters)	440 - 630
Sanitary and industrial (cubic meters)	4,400 - 10,000
Sanitary sewage (million liters)[c]	83 - 200
Industrial wastewater (million liters)	42 - 105
Low-level radioactive (cubic meters, after treatment)	2,100 - 3,500

a. Sources: TRW (1999a, page 81); TRW (1999b, pages 6-38 and 6-39).
b. To convert cubic meters to cubic feet, multiply by 35.314.
c. To convert liters to gallons, multiply by 0.26418.

DOE would dispose of demolition debris and sanitary and industrial solid waste in the onsite landfill (or at the Nevada Test Site), and sanitary sewage and industrial wastewater in the onsite septic systems and industrial wastewater system. After disposing of the waste and wastewater, DOE would close the landfill and evaporation ponds in a manner that met applicable requirements.

The Nevada Test Site landfills would have to continue operating past their estimated lives and to expand as needed. The 10C landfill, which accepts demolition debris, has an estimated 70-year operational life; the Area 23 landfill, which is used for sanitary and industrial solid waste disposal, has a 100-year estimated life (DOE 1995f, pages 8 and 9).

DOE would continue to dispose of hazardous and low-level radioactive wastes off the site. The Department would ship hazardous waste to an offsite vendor with the appropriate permits and available treatment and disposal capacity and would ship low-level radioactive waste to a Nevada Test Site disposal facility. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) shows that the available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come. Therefore, hazardous waste generated during closure activities would be likely to have a very small impact on the capacity for treatment and disposal at commercial facilities. The disposal of low-level radioactive waste generated during repository closure at the Nevada Test Site would affect the disposal capacity about one-tenth of 1 percent.

Table 4-42 lists the waste types that repository activities would generate from construction through closure and the total estimated waste quantities for the nine thermal load scenario and packaging combinations. The table summarizes waste quantities for all phases of the Proposed Action.

If not recycled, dual-purpose canisters would add an estimated 44,000 cubic meters (1.6 million cubic feet) of low-level waste under each of the dual-purpose canister packaging scenarios (Koppenaal 1998a, all; TRW 1999a, page 76).

Table 4-42. Estimated waste quantities for Proposed Action.[a]

Waste type	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Construction and demolition debris (cubic meters)[e]	150,000	100,000	120,000	150,000	100,000	120,000	150,000	100,000	120,000
Hazardous (cubic meters)	7,700	3,500	3,500	7,700	3,500	3,500	7,700	3,500	3,500
Sanitary and industrial solid (cubic meters)	85,000	73,000	74,000	85,000	73,000	74,000	110,000	98,000	99,000
Sanitary sewage (million liters)[f]	2,000	1,800	1,800	2,000	1,800	1,800	2,200	1,900	2,000
Industrial wastewater (million liters)	980	870	870	1,000	900	900	1,600	1,500	1,500
Low-level radioactive (cubic meters after treatment)	71,000	21,000	29,000	71,000	21,000	29,000	71,000	21,000	29,000

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. UC = uncanistered.
c. DISP = disposable canister.
d. DPC = dual-purpose canister.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.2641.

4.1.12.3 Impacts from Hazardous Materials

The operation of the Yucca Mountain Repository would require the use of hazardous materials including paints, solvents, adhesives, sodium hydroxide, dry carbon dioxide, aluminum sulfate, sulfuric acid, and compressed gases. DOE has programs and procedures in place to procure and manage hazardous materials (DOE 1996h, all), ensuring their procurement in the appropriate quantities and storage under the proper conditions. At the repository, DOE would use an automated inventory management program (TRW 1999a, page 62) to control and track inventory.

4.1.12.4 Waste Minimization and Pollution Prevention

DOE would develop a waste minimization and pollution prevention awareness plan similar to the plan it has used during site characterization activities at Yucca Mountain (DOE 1997h, all). The goal of this new plan would be to minimize quantities of generated waste and to prevent pollution. To achieve this goal, DOE would establish requirements for each onsite organization and identify methods and activities to reduce waste quantities and toxicity.

DOE would recycle materials to the extent that it was cost-effective, feasible, and environmentally sound. Table 4-43 lists estimated quantities of materials that DOE would recycle during the life of the repository.

DOE has identified pollution prevention opportunities in the repository conceptual design process. The Waste Treatment Building design includes recycling facilities for the large aqueous low-level radioactive waste stream [690,000 liters (182,000 gallons) per year for the uncanistered packaging scenario] (DOE 1997l, page 23) that would result from decontamination activities. Wastewater recycling would greatly reduce water demand by repository facilities, as well as the amount of wastewater that would otherwise require disposal. In addition, DOE would use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would generate less waste than other techniques.

In addition, DOE would use automated maintenance tracking and inventory management programs that would interface with the procurement system (TRW 1999a, page 62). These systems would assist in ensuring the proper maintenance of equipment through a preventive maintenance approach, which could

Table 4-43. Estimated recyclable material quantities.[a]

Material	UC[b]	DISP[c]	DPC[d]
High thermal load			
Recyclables (cubic meters)[e,f]	210,000	170,000	180,000
Steel (metric tons)[g]	37,000	27,000	31,000
Dual-purpose canisters[h] (cubic meters)	NA[i]	NA	44,000
Oils and lubricants (liters)[j]	28,000,000	28,000,000	28,000,000
Intermediate thermal load			
Recyclables (cubic meters)	210,000	170,000	180,000
Steel (metric tons)	37,000	27,000	31,000
Dual-purpose canisters (cubic meters)	NA	NA	44,000
Oils and lubricants (liters)	39,000,000	39,000,000	39,000,000
Low thermal load			
Recyclables (cubic meters)	260,000	230,000	240,000
Steel (metric tons)	37,000	27,000	31,000
Dual-purpose canisters (cubic meters)	NA	NA	44,000
Oils and lubricants (liters)	63,000,000	63,000,000	63,000,000

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Nonhazardous, nonradioactive materials such as paper, plastic, glass, and nonferrous metals.
f. To convert cubic meters to cubic feet, multiply by 35.314.
g. To convert metric tons to tons, multiply by 1.1023.
h. Dual-purpose canisters would be recycled if appropriate, with regard to protection of the environment and cost-effectiveness. Estimated weight is 220,000 metric tons.
i. NA = not applicable.
j. To convert liters to gallons, multiply by 0.26418.

lead to less waste generation. Inventory management would prevent overstocking that could allow chemicals and other items to exceed their shelf lives and become waste.

4.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to identify and address the potential for their activities to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines to determine if disproportionately high and adverse impacts to human health or the environment on minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

The environmental justice analysis brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. If any of these analyses were to predict high and adverse impacts to the human population in general, then an environmental justice analysis would determine if those impacts could occur in a disproportionately high and adverse manner to minority or low-income populations. The basis for making this determination is a comparison of the areas of large impacts with maps that indicate high percentages of minority or low-income populations as reported by the Bureau of the Census.

The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (CEQ 1997, all).

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (CEQ 1997, all)]. Nevada has a minority population of 21 percent (Bureau of the Census 1992a, Tables P8 and P12). For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) having a minority population of 31 percent or higher.

Nevada has a low-income population of 10 percent. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (OMB 1999, all). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census block groups having a low-income population of 20 percent or higher.

The environmental justice analysis involves a two-stage assessment of the potential for disproportionately high and adverse impacts on minority and low-income populations:

- First, a review of the activities included in the Proposed Action to determine if they are likely to result in any high and adverse human health impacts

- Second, if the first-stage review identified any high and adverse impacts to human populations in general, an analysis of whether minority or low-income populations would be affected disproportionately

The EIS analyses determined that the impacts that could occur to public health and safety would be small on the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionate impacts.

4.1.13.2 Performance Confirmation, Construction, Operation and Monitoring, and Closure

Cultural Resources

DOE has implemented a worker education program on the protection of these resources to limit direct impacts to cultural resources, especially inadvertent damage and illicit artifact collecting. If significant data recovery (artifact collection) were required during construction and operation, DOE would initiate additional consultations with Native American groups to determine appropriate involvement. Further, archaeological resources and potential data recovery would be managed and conducted through consultations with the State Historic Preservation Officer or the Advisory Council on Historic Preservation.

Public Health and Safety

DOE has identified potential impacts to public health and safety from repository construction and operation (Section 4.1.7). However, DOE expects such impacts to be small. Because contamination of edible plants and animals would be unlikely from construction, operation and monitoring, and eventual closure of the repository, impacts to persons leading subsistence lifestyles would be unlikely.

Land Use

Direct land-use impacts from the Proposed Action would be low on members of the public because of the existing restriction of site access. There are no communities with high percentages of minority or low-income populations near the proposed repository site.

Socioeconomics

Because of the large population and workforce in the region of influence, socioeconomic impacts from repository construction and operation would be small. During the construction phase and the operation and monitoring phase, the regional workforce would increase less than 0.5 percent above the baseline level (see Section 4.1.6). Changes to the baseline regional population would not be greater than 0.5 percent for the duration of the entire project. Because the Proposed Action would generate minimal impacts to employment and population, potential socioeconomic impacts would be small.

DOE would continue its Native American Interaction Program to help manage cultural resources during construction and operation.

Air Quality

Impacts to air quality from the Proposed Action would be small. Furthermore, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust and construction activities that could produce vehicle emissions.

Noise

Impacts to sensitive noise receptors from the Proposed Action would not be likely because no sensitive noise receptors live in the Yucca Mountain region. Furthermore, there are no low-income or minority communities adjacent to the site.

4.1.13.3 Environmental Justice Impact Analysis Results

This analysis uses information from Sections 4.1.1 through 4.1.9. Those sections address impacts from all phases of the Proposed Action—construction, operation and monitoring, and closure. As noted above, DOE expects that the impacts of the Proposed Action would be small on the population as a whole. DOE has not identified any subsection of the population, including minority and low-income populations, that would receive disproportionate impacts. Accordingly, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 A Native American Perspective

In reaching the conclusion that there would be no disproportionately high and adverse impacts on minorities or low-income populations, DOE acknowledges that people from many Native American tribes have used the area proposed for the repository as well as nearby lands (AIWS 1998, page 2-1), that the lands around the site contain cultural, animal, and plant resources important to those tribes, and that the implementation of the Proposed Action would continue restrictions on free access to the repository site. DOE acknowledges that Native American people living in the Yucca Mountain vicinity have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action.

Native American people living in the Yucca Mountain vicinity hold views and beliefs about the relationship between the proposed repository and the surrounding region that they have expressed in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all). Concerning the approach to daily life, the authors of that document, who represent the Western Shoshone, Owens Valley Paiute and Shoshone, Southern Paiute, and other Native American organizations, state:

> *…we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence (AIWS 1998, page 2-9).*

The authors discuss the cultural significance of Yucca Mountain lands to Native American people:

> *American Indian people who belong to the CGTO (Consolidated Group of Tribes and Organizations) consider the YMP lands to be as central to their lives today as they have been since the creation of their people. The YMP lands are part of the holy lands of Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone people (AIWS 1998, page 2-20).*

and:

> *The lack of an abundance of artifacts and archaeological remains does not infer that the site was not used historically or presently and considered an integral part of the cultural ecosystem and landscape (AIWS 1998, page 2-10).*

The authors address the continuing denial of access to Yucca Mountain lands:

> *One of the most detrimental consequences to the survival of American Indian culture, religion, and society has been the denial of free access to their traditional lands and resources (AIWS 1998, page 2-20).*

and:

> *No other people have experienced similar cultural survival impacts due to lack of free access to the YMP area (AIWS 1998, page 2-20).*

The authors recognize that past restrictions on access have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (AIWS 1998, Section 3.1.1). However, the authors express concerns of Native American people regarding use of the repository:

> *The past, present, and future pollution of these holy lands constitutes both Environmental Justice and equity violations. No other people have had their holy lands impacted by YMP-related activities (AIWS 1998, page 2-20).*

and:

> *Access to culturally significant spiritual places and use of animals, plants, water and lands may cease because Indian people's perception of health and spiritual risks will increase if a repository is constructed (AIWS 1998, page 3-1).*

Even after closure and reclamation, the presence of the repository would represent an irreversible impact to traditional lands and other elements of the natural environment in the view of Native Americans.

Regarding the transportation of spent nuclear fuel and high-level radioactive waste, the authors state:

> *…health risks and environmental effects resulting from the construction and operation of the proposed intermodal transfer facility (ITF) and the transportation of high-level waste and spent nuclear fuel is considered by Indian people to be disproportionately high. This is attributed primarily to the consumption patterns of Indian people who still use these plants and animals for food, medicine, and other related cultural or ceremonial purposes (AIWS 1998, page 2-19).*

and:

> *The anticipated additional noise and interference associated with an ITF* [Intermodal Transfer Facility] *and increased transportation may disrupt important ceremonies that help the plants, animals, and other important cultural resources flourish, or may negatively impact the solitude that is needed for healing or praying (AIWS 1998, page 2-19).*

DOE recognizes that Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as established by treaty, statute, legal precedent, and the U.S. Constitution. For this reason DOE will consult with tribal governments and will work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that could affect tribes; to continue the protection of Native American cultural resources, sacred sites, and potential traditional cultural properties; and to implement any appropriate mitigation measures.

4.1.14 IMPACTS OF THERMAL LOAD AND PACKAGING SCENARIOS

This section summarizes and compares the short-term environmental impacts for the three thermal load scenarios. These scenarios for the repository are high thermal load (85 MTHM per acre), intermediate thermal load (60 MTHM per acre) and low thermal load (25 MTHM per acre).

Overall the EIS analysis found that differences in environmental impacts for the three thermal load scenarios would be low and that the differences between the scenarios would be small. More specifically:

- All of the short-term impacts from repository activities would be small, both to workers and to the public.

- Long-term impacts to the public for the three thermal load scenarios would be essentially the same for collective dose and for latent cancer fatalities. They would be low (0.005 to 0.02 latent cancer fatality). Over the first 10,000 years, the risk of a latent cancer fatality to the maximally exposed individual would also be low (from 0.000001 to 0.000003) at 20 kilometers (about 12 miles) downgradient from Yucca Mountain. Individual dose rates would be highest for the high thermal load scenario and lowest for the low thermal load scenario.

- Short-term impacts for the surface-water, biological and soil, cultural, aesthetics, noise, and environmental justice resource areas would be small regardless of the thermal load scenario.

Short-term environmental impacts for activities at the repository as a function of packaging scenarios include:

- The greatest impacts for repository-related activities would be associated with the uncanistered packaging scenario with the exception of the generated volumes of solid and industrial wastes. For these wastes, the greatest impacts would result from the dual-purpose and disposable shipping packaging scenarios because these two types of shipping package would eventually become waste.

- Differences in impacts among the packaging scenarios would not be large, generally between 10 and 20 percent.

4.1.15 IMPACTS FROM MANUFACTURING DISPOSAL CONTAINERS AND SHIPPING CASKS

This section discusses the potential environmental impacts from the manufacturing of disposal containers and shipping casks required by the Proposed Action to dispose of spent nuclear fuel and high-level radioactive waste permanently at a monitored geologic repository at Yucca Mountain. This analysis considers transportation overpacks that would provide radiation shielding in the same manner as a shipping cask but that DOE would use only in conjunction with disposable canisters and dual-purpose canisters to be shipping casks without baskets or other internal configurations.

4.1.15.1 Overview

DOE followed the overall approach and analytical methods used for the environmental evaluation and the baseline data directly from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (USN 1996a, all). DOE's evaluation focuses on ways in which the manufacture of the disposal containers and shipping casks could affect environmental attributes and resources at a representative manufacturing site. It is not site-specific because more than one manufacturer probably would be required to meet the production schedule requirements for component delivery, and the location of the companies chosen to manufacture disposal containers and shipping casks is not known. The companies and, therefore, the actual manufacturing sites would be determined by competitive bidding.

The analysis used a representative manufacturing site based on five facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel. The concept of a representative site was used in the Navy EIS (USN 1996a, page 4-1), and the representative site used in this analysis was defined in the same way, using the same five existing manufacturing facilities with the same attributes. The facilities used to define the representative site are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee (USN

1996a, page 4-17). All of these facilities make components for firms with cask and canister designs approved by the Nuclear Regulatory Commission.

The analysis assumed that the manufacturing facilities and processes being used are similar to the facilities and processes that would produce disposal containers and shipping casks for the Yucca Mountain Repository. Therefore, the analysis considered the manufacturing processes used at these facilities and the total number of disposal containers and shipping casks required to implement each packaging scenario. The analysis assumed that the manufacture of disposal containers and shipping casks would occur at one representative site, but DOE recognizes that it probably would occur at more than one site. The assumption of one manufacturing site is conservative (that is, it tends to overestimate impacts) because it concentrates the potential impacts.

In addition, the analysis of disposal container and cask manufacturing evaluated the use of materials and the potential for impacts to material markets and supplies.

Section 4.1.15.3 describes the disposal containers and shipping casks. Section 4.1.15.4 discusses pertinent information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 describes environmental impacts on air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.15.2 Components and Production Schedule

Table 4-44 lists the quantities of disposal containers and shipping casks analyzed for the packaging scenarios described in Chapter 2. Table 4-44 includes disposal containers for naval spent nuclear fuel that would be emplaced in Yucca Mountain but does not include shipping casks for naval spent nuclear fuel. Shipping casks for naval spent nuclear fuel are owned and managed by the Navy. USN (1996a, all) analyzed environmental impacts for production of naval spent nuclear fuel canisters and shipping casks. Because naval spent nuclear fuel represents less than 4 percent of the inventory to be emplaced in the repository, the production of naval spent nuclear fuel casks would not add much to the impacts described in the following sections.

Table 4-44. Quantities of disposal containers and shipping casks for the Yucca Mountain Repository.[a]

		Packaging scenario[b]		
Component	Description	UC	DISP	DPC
Disposal containers[c]	Containers for disposal of SNF and HLW[d]	10,200	11,400	10,200
Rail shipping casks or overpacks[f]	Storage and shipment of SNF and HLW	0	100	110
Legal-weight truck shipping casks[f]	Storage and shipment of uncanistered fuel	120	10	10

a. The number of containers is an approximation but is based on the best available estimates.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Source: TRW (1999c, Section 6); values have been rounded.
d. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
e. A larger number of disposal containers is required for disposable canisters because they cannot be packed as densely as other canisters.
f. Cask fleet developed from Ross (1998, all); JAI (1996, all); TRW (1998j, Table 12, pages 17 and 18).

As currently planned, all of the components listed in Table 4-44 would be manufactured over 24 years to support emplacement in the repository. Manufacturing activity would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period.

4.1.15.3 Components

Disposal Containers

The disposal container would be the final outside container used to package the spent nuclear fuel and high-level radioactive waste emplaced in the repository. The basic design calls for a cylindrical vessel with an outer layer of A 516 carbon steel that would be 100 millimeters (3.9 inches) thick and an inner liner of corrosion-resistant high-nickel alloy (C-22) that would be 20 millimeters (0.8 inch) thick (TRW 1999c, Section 6.0, page 6-1). The flat end pieces would be 110-millimeter (4.3-inch)-thick carbon steel and 25-millimeter (1-inch)-thick high-nickel alloy. The bottom end pieces would be welded to the cylindrical body at the fabrication shop, and the top end pieces would be welded in place after the placement of spent nuclear fuel or high-level radioactive waste in the container at the repository. About 16 different disposal container designs would be used for different types of spent nuclear fuel and high-level radioactive waste. The designs would vary in length from 3.8 to 6.2 meters (12 to 20 feet) and the outside diameters would range from 1.3 to 2 meters (4.3 to 6.6 feet). In addition, the internal configurations of the containers would be different to accommodate different uncanistered spent nuclear fuel configurations and a variety of spent nuclear fuel and high-level radioactive waste disposable canisters. The mass of an empty disposal container would range from about 21 to 38 metric tons (23 to 42 tons) (TRW 1999c, Section 4.0, pages 4-16 to 4-21).

Casks for Rail and Legal-Weight Truck Shipments

DOE would use two basic kinds of shipping cask designs—rail and truck—to ship spent nuclear fuel and high-level radioactive waste to the repository. The design of a specific cask would be tailored to the type of material it would contain. For example, rail and truck casks that could be used to ship commercial spent nuclear fuel would be constructed of stainless- or carbon-steel plate materials formed into cylinders and assembled to form inner and outer cylinders (USN 1996a, pages 4-3 and 4-4). A depleted uranium or lead liner would be installed between the stainless- or carbon-steel cylinders, and a vessel bottom with lead or depleted uranium between the inner and outer stainless- or carbon-steel plates would be welded to the cylinders. A support structure that could contain neutron-absorbing material would be welded into the inner liner, if required. A polypropylene sheath would be placed around the outside of the cylinder for neutron shielding. After spent nuclear fuel assemblies were inserted into the cask, a cover with lead or depleted uranium shielding would be bolted to the top of the cylinder to close and seal it. Transportation overpacks would be very similar in design and construction to shipping casks but would not have an internal support structure for the spent nuclear fuel because they would be used only for dual-purpose or disposable canisters.

For commercial spent nuclear fuel, casks and overpacks are typically 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. These casks are designed to be horizontal when shipped. Rail casks presently used to ship naval spent nuclear fuel are shorter and are designed to sit upright on railcars. Empty truck casks typically weigh from 21 to 2 metric tons (about 23 to 24 tons). Empty rail casks (or overpacks) for commercial spent nuclear fuel typically weigh from 59 to 91 metric tons (65 tons to a little over 100 tons). The corresponding weights when loaded with spent nuclear fuel range between 22 and 24 metric tons (24 and 26 tons) for truck casks and between 64 and 110 metric tons (70 and 120 tons) for rail casks. For protection during shipment, large removable impact limiters of aluminum honeycomb or other crushable impact-absorbing material would be placed over the ends (JAI 1996, all).

4.1.15.4 Existing Environmental Settings at Manufacturing Facilities

Because there are facilities that could meet the projected manufacturing requirements, the assessment concluded that no new construction would be necessary and that there would be no change in land use for the manufacture of disposal containers and shipping casks. Similarly, cultural, aesthetic, and scenic resources would remain unaffected. Ecological resources, including wetlands, would not be affected because existing facilities could accommodate the manufacture of disposal containers and shipping casks and new or expanded facilities would not be required. Some minor increases in noise, traffic, or utilities would be likely, but none of these increases would result in impacts on the local environment.

Water consumption and effluent discharge during the manufacture of disposal containers and shipping casks would be typical of a heavy manufacturing facility and would represent only a small change, if any, from existing rates. Similarly, effluent discharges would not increase enough to cause difficulty in complying with applicable local, state, and Federal regulatory limits, and would be unlikely to result in a discernible increase in pollutant activity.

Accordingly, the following paragraphs contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 evaluates the environmental impacts to these resource areas for a representative site.

Air Quality

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas in which the reference manufacturing facilities are located. The principal criteria pollutants for cask manufacturing facilities are ozone, carbon monoxide, and particulate matter (PM_{10}). Areas where ambient air quality standards are not exceeded, or where measurements have not been made, are considered to be in attainment. Areas where the air quality violates Federal or state regulations are in nonattainment and subject to more stringent regulations. Typical existing container and cask manufacturing facilities are in nonattainment areas for ozone and in attainment areas for carbon monoxide and particulate matter.

Because most of the existing typical manufacturing facilities are in nonattainment areas for ozone, the analysis assumed that the representative site would be in nonattainment for ozone and that ozone would be the criteria pollutant of interest. Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production. For the areas in which the reference manufacturing facilities are located, an average of 3,400 metric tons (approximately 3,800 tons) of volatile organic compounds and 39,000 metric tons (approximately 43,000 tons) of nitrous oxides were released to the environment in 1990, the latest year for which county-level data are available (USN 1996a, page 4-5).

Health and Safety

Data on the number of accidents and fatalities associated with cask and canister fabrication at the representative manufacturing location were based on national incidence rates for the relevant sector of the economy. In 1992, the last year for which statistics are available, the occupational fatality rate for the sector that includes all manufacturing was 3 per 100,000 workers; the occupational illness and injury rate for fabricated plate work manufacturing in 1992 was 6.3 per 100 full-time workers (USN 1996a, page 4-5).

The manufacture of hardware for each of the packaging scenarios would be likely to be in facilities that have had years of experience in rolling, shaping, and welding metal forms, and then fabricating large containment vessels similar to the required disposal containers and shipping casks for nuclear materials. Machining operations at these facilities would involve standard procedures using established metal-working equipment and techniques. Trained personnel familiar with the manufacture of large, multiwall, metal containment vessels would use the equipment necessary to fabricate such items. Because of this experience and training, DOE anticipates that the injury and illness rate would be equal to or lower than the industry rates.

Socioeconomics

Each of the five manufacturing facilities examined in this analysis is in a Metropolitan Statistical Area. The counties comprising each Metropolitan Statistical Area define the affected socioeconomic environment for each facility. The populations of the affected environments associated with the five facilities ranged from about 430,000 to 970,000 in 1992 (USN 1996a, page 4-6). In 1995 output (the value of goods and services produced in the five locations) ranged from $18 billion to $55 billion, income (wages, salaries, and property income) ranged from $9 billion to $26 billion, employment ranged from 245,000 to 670,000 in 1995, and plant employment ranged from 25 to 995 (USN 1996a, page 4-6). Based on averages of this information, the representative manufacturing location has a population of about 640,000 and the facility employs 480. Local output in the area is $30 billion, local income is $15 billion, and local employment is 390,000.

4.1.15.5 Environmental Impacts

As mentioned in Section 4.1.15.4, this evaluation considered only existing manufacturing facilities, so environmental impact analyses are limited to air quality, health and safety, waste generation, and socioeconomics. In addition, this section contains a qualitative discussion of environmental justice.

4.1.15.5.1 *Air Quality*

The analysis used the baseline data and methods developed in USN (1996a, Section 4.3) to estimate air emissions from manufacturing sites for the production of disposal containers and shipping casks. Criteria pollutants and hazardous air pollutants were considered, and predicted emissions were compared with typical regional or county-wide emissions to determine potential impacts of the emissions on local air quality.

Potential emissions were evaluated for a representative manufacturing location using the ambient air quality characteristics of typical manufacturing facilities, as described in Section 4.1.15.4. The analysis assumed that the representative location used for this analysis would be in a nonattainment area for ozone and in attainment areas for carbon monoxide and particulate matter. Therefore, ozone was the only criteria pollutant analyzed. Ozone is not normally released directly to the atmosphere, but is produced in a complex reaction of precursor chemicals (volatile organic compounds and nitrous oxides) and sunlight. This section evaluates the emissions of these precursors.

The reference air emissions associated with the manufacture of disposal containers and shipping casks were developed using the emissions resulting from manufacturing similar components (USN 1996a, page 4-6) and were normalized based on the number of work hours required for the manufacturing process. The analysis prorated these reference emissions on a per-unit basis to calculate annual emissions at the reference manufacturing site, assuming emissions from similar activities would be proportional to the number of work hours in the manufacturing process. To provide reasonable estimates of emissions, the analysis assumed that the volatile organic compounds used as cleaning fluids would evaporate fully into the atmosphere as a result of the cleaning processes used in manufacturing. The estimates of emissions were based on the total number of disposal containers and shipping casks manufactured over 24 years for each packaging scenario.

Table 4-45 lists the estimated annual average and estimated total 24-year emissions from the manufacture of disposal containers and shipping casks at the representative facility for each packaging scenario. Estimated annual average emissions of volatile organic compounds would vary from 0.58 to 0.61 metric ton (approximately 0.64 to 0.67 ton) a year. Nitrous oxides would be the largest emission, varying from 0.75 to 0.78 metric ton (approximately 0.83 to 0.86 ton) a year for the packaging scenarios. Annual

Table 4-45. Ozone-related air emissions (metric tons)[a] at the representative manufacturing location for the different packaging scenarios.

Compound	Measure	Packaging scenario[b] UC	DISP	DPC
Volatile organic compounds	Annual average	0.60	0.61	0.58
	24-year total	15	15	14
	Percent of *de minimis*[c]	6.6%	6.7%	6.4%
Nitrogen oxides	Annual average	0.78	0.78	0.75
	24-year total	19	19	18
	Percent of *de minimis*[c]	8.6%	8.6%	8.2%

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. *De minimis* level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons per year of volatile organic compounds or nitrogen oxides (40 CFR 51.853).

average emissions from disposal container and shipping cask manufacturing under any of the scenarios would be less than 0.02 percent of regional emissions of volatile organic compounds and 0.002 percent of regional emissions of nitrous oxides. Emissions from the manufacture of disposal containers and shipping casks would contain a relatively small amount of ozone precursors compared to other sources.

The examination of the packaging scenarios assumed that the emissions of volatile organic compounds and nitrous oxides were new sources; these emissions were compared with emission threshold levels (emission levels below which conformity regulations do not apply). There are different categories of ozone nonattainment areas based on the sources of ozone and amount of air pollution in the region. The different categories have different emission threshold levels (40 CFR 51.853).

For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year. Table 4-45 also lists the percentage of volatile organic compounds and nitrous oxides from the manufacture of disposal containers and shipping casks in relation to the emission threshold level of an extreme ozone nonattainment area. Air emissions from the manufacture of disposal containers and shipping casks would vary depending on the packaging scenario, with ranges of 6.4 to 6.7 percent and 8.2 to 8.6 percent of the emission threshold levels for volatile organic compounds and nitrous oxides, respectively. In all of the packaging scenarios, component manufacturing would not be likely to fall under the conformity regulations because the predicted emissions of volatile organic compounds and nitrous oxides would be well below (less than 10 percent of) the emission threshold level of 9.1 metric tons per year. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each designated manufacturing facility.

States with nonattainment areas for ozone could place requirements on many stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds and nitrous oxides. Various options such as additional scrubbers, afterburners, or carbon filters would be available to control emissions of these compounds to comply with limitations.

4.1.15.5.2 *Health and Safety*

The analysis used data on the metal fabrication and welding industries from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate steel and steel objects similar to disposal containers and shipping casks (USN 1996a, page 4-8). The expected number of injuries and fatalities were computed by multiplying the number of work years by the injury and fatality rate for each occupation.

Table 4-46 lists the expected number of injuries and illnesses and fatalities for each packaging scenario based on the work years required to produce the number of disposal containers and shipping casks needed over 24 years. Injuries and illnesses would range from 265 to 276. Fatalities would be unlikely.

Table 4-46. Injuries, illnesses, and fatalities over 24 years at the representative manufacturing location for the packaging scenarios.

Parameter	Packaging scenario[a]		
	UC	DISP	DPC
Injuries and illnesses	275	276	265
Fatalities	0.13	0.13	0.13

a. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

The required number of disposal containers and shipping casks would not place unusual demands on existing manufacturing facilities. Thus, none of the packaging scenarios would be likely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that are more proceduralized, both of which lead to improved worker safety.

4.1.15.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost data for disposal containers (TRW 1999c, Sections 5 and 6) and per-unit cost of shipping casks (TRW 1998j, Table 12, pages 17 and 18)

- Total number of disposal containers and shipping casks to be manufactured (TRW 1999c, Section 6)

- Economic data for the environmental setting for each facility to calculate the direct and secondary economic impacts of disposal container and shipping cask manufacturing on the local economy (BEA 1992, all)

  – Direct effects would occur as manufacturing facilities purchased materials, services, and labor required for manufacturing.

  – Secondary effects would occur as industries and households supplying the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, thereby generating additional socioeconomic impacts.

Impacts were measured in terms of output (the value of goods and services produced), income (wages, salaries, and property income), and employment (number of jobs).

The socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products (BEA 1992, all). To perform the analysis, DOE obtained the product, income, and employment multipliers for the states where the five existing manufacturing facilities are located. (Multipliers account for the secondary effects on an area's economy in addition to providing direct effects on its economy). The multipliers were averaged to produce composite multipliers for a representative manufacturing location. The composite multipliers were used to analyze the impacts of each alternative. Table 4-47 lists the state-specific multipliers and the composite multipliers.

The analysis was limited to estimating the direct and secondary impacts of manufacturing activities. No assessment was made of the impacts of manufacturing activities on local jurisdictions. Such an analysis would include the estimation of impacts on county and municipal government and school district revenues and expenditures. Because the production of disposal containers and shipping casks probably

Table 4-47. Economic multipliers for fabricated metal products.[a]

State	Final demand multiplier ($) Products	Final demand multiplier ($) Earnings	Direct effect multiplier (number of jobs)
Massachusetts	1.8927	0.5555	2.2050
North Carolina	1.9145	0.5426	2.1544
Ohio	2.6019	0.7260	3.1064
Pennsylvania	2.5697	0.7194	2.8552
Tennessee	2.1379	0.6107	2.5314
Composite	2.2233	0.6308	2.5705

a. Source: Bureau of the Census (1992h, all).

would occur at existing facilities alongside existing product lines, a substantial population increase due to workers moving into the vicinity of the manufacturing sites in a given year under a packaging scenario would be unlikely. Due to this lack of demographic impacts, meaningful change in the disposition of local government or school district revenues and expenditures would be unlikely. Because substantial population increases would not be likely, the analysis did not consider impacts on other areas of socioeconomic concern, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period. The impacts of each packaging scenario were compared to the baseline at the representative location in 1995, with results expressed in millions of 1998 dollars. No attempt was made to forecast local economic growth or inflation rates for the representative location because of the non-site-specific nature of the analysis.

Table 4-48 lists the impacts of each packaging scenario on output, income, and employment at the representative manufacturing location. The impacts include the percent of each scenario in relation to overall output, income, and employment in the economy.

Table 4-48. Socioeconomic impacts for packaging scenarios at the representative manufacturing location.

Packaging scenario	Average annual output[a]		Average annual income		Average annual employment	
	$ (millions)	Percent impact[b]	$ (millions)	Percent impact	Person-years	Percent impact
Uncanistered	360	1.2	102	0.68	470	0.12
Dual-purpose canister	365	1.2	104	0.69	450	0.12
Disposable canister	310	1.0	89	0.59	470	0.12

a. Annual output and income impacts are expressed as millions of 1998 dollars.
b. Percent impact refers to the percentage of the baseline data discussed in Section 4.1.14.4 for the representative site.

Local Output

The average annual output impacts of each scenario would range from about $310 million to about $365 million (Table 4-48). Output generated from each scenario would increase total local output from between 1.0 percent and 1.2 percent, on average, over the 24-year manufacturing period.

Local Income

The average annual income impacts of each packaging scenario would range from about $89 million to about $104 million (Table 4-48). Income generated from each scenario would increase total local income by between 0.59 percent and 0.69 percent, on average, over the 24-year manufacturing period.

Local Employment

The average annual employment impacts of each packaging scenario would range from about 450 to about 470 work years (Table 4-48). Employment generated from any of the packaging scenarios would increase total local employment about 0.12 percent, on average, over the 24-year manufacturing period.

4.1.15.5.4 *Impacts on Material Use*

To the extent available, DOE based the calculations of the quantities of materials it would use for the manufacture of each disposal container and shipping cask on engineering specifications for each hardware component. This information was provided by the manufacturers of systems either designed or under licensing review (USN 1996a, Sections 3.0, 4.1.1, and Appendix D; TRW 1999c, all), or from conceptual design specifications for technologies still in the planning stages (JAI 1996, all). Data on per-unit material quantities for each component were combined with information on the number of disposal containers and shipping casks to be manufactured during each packaging scenario. In addition, the analysis assessed the impact of component manufacturing for each scenario on the total U.S. production (or availability in the United States, if not produced in this country) of each relevant input material. The results of the assessment are expressed in terms of percent impacts on total U.S. domestic production of most commodities.

Table 4-49 lists estimated total quantities of materials that DOE would need for each packaging scenario during the 24-year period along with the annual average requirement for each material. For each scenario the largest material requirement by weight would be steel, ranging from about 260,000 to about 280,000 metric tons (280,000 to 310,000 tons).

Table 4-49. Material use (metric tons)[a] for packaging scenarios.

	Basic material use per scenario[b]					
	UC		DISP		DPC	
Material	Total	Annual	Total	Annual	Total	Annual
Aluminum	1,500	63	77	3	1,500	63
Chromium[c]	14,000	590	12,000	500	15,000	620
Copper	36	1	146	6	95	4
Depleted uranium	880	37	1,300	55	120	5
Lead	430	18	1,500	63	3,000	139
Molybdenum[d]	6,000	250	6,600	280	6,000	260
Nickel[e]	29,000	1,200	29,000	1,200	30,000	1,200
Steel	280,000	12,000	260,000	11,000	280,000	12,000

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Chromium estimated as 29 percent of stainless steel and 22 percent of high-nickel alloy.
d. Molybdenum estimated as 13.5 percent of high-nickel alloy.
e. Stainless steel assumed to be 18.5 percent nickel and high-nickel alloy assumed to be 58 percent nickel.

Table 4-50 compares the annual U.S. production capacity to the annual requirements for the materials each scenario would use. With the exception of chromium and nickel, consumption for each scenario for the 24-year manufacturing period would be less than 0.5 percent of the annual U.S. production.

Therefore, the use of aluminum, copper, lead, molybdenum, or steel would not produce a noteworthy increased demand and should not have a meaningful effect on the supply of these materials.

The annual requirement for chromium as a component in stainless-steel and high-nickel alloy ranges from about 0.48 percent to about 0.59 percent of the annual U.S. production. Most chromium, which is

Table 4-50. Annual amount (metric tons)[a] of material required for manufacturing, expressed as a percent of annual U.S. domestic production, for each packaging scenario.

		Packaging scenario[b]					
		UC		DISP		DPC	
Material	Production[c]	Annual	Percent	Annual	Percent	Annual	Percent
Aluminum	5,000,000	63	0.0013	3	0.0001	63	0.0013
Chromium	104,000	590	0.57	500	0.48	620	0.59
Copper	1,900,000	1	0.0001	6	0.0003	4	0.0002
Depleted uranium	14,700[d]	37	0.25	55	0.38	5	0.034
Lead	430,000	18	0.0042	63	0.015	140	0.032
Molybdenum	57,000	250	0.45	280	0.48	260	0.045
Nickel	14,600	1,200	8.3	1,200	8.3	1,200	8.4
Steel	91,500,000	12,000	0.013	11,000	0.012	12,000	0.013

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Source: Bureau of the Census (1997, Table 1155, page 700, and Table 1244, page 756).
d. Source: USN (1996a, page 4-10).

an important constituent of many types of stainless steel, is imported into the United States and is classified as a Federal Strategic and Critical Inventory material. For comparative purposes, the maximum total 24-year program requirement of about 14,000 metric tons (17,000 tons) can be evaluated as a percentage of the 1994 strategic chromium inventory of 1.04 million metric tons (1.15 million tons) (Bureau of the Census 1997, Table 1159, page 702). The total repository program need would be about 1.5 percent of the strategic inventory. With the strategic inventory to support the program demand, chromium use should not cause any market or supply impacts.

Annual nickel use as a component in stainless steel and corrosion-resistant high-nickel alloys appears, relatively, the most important in comparison to U.S. production. The magnitude of the comparison is the result of low U.S. production because the United States imports most of the nickel it uses. Although the annual U.S. production of nickel is only 14,600 metric tons (16,100 tons), the annual U.S. consumption is 158,000 metric tons (174,000 tons) (Bureau of Census 1997, Table 1155, page 700). This annual consumption is supported by a robust world production of 1.04 million metric tons (1.15 million tons) (Bureau of the Census 1997, Table 1158, page 702). The maximum annual program need is a little less than 1 percent of the U.S. consumption and about 0.1 percent of world production. Canada is a major world supplier of nickel. DOE does not anticipate that the maximum program demand would affect the U.S. or world nickel markets.

The annual amount of depleted uranium used over 24 years would range from 0.25 percent to 0.38 percent of the total U.S. annual production. These requirements would be small. Given the limited alternative uses of this material and the large current inventory of surplus depleted uranium hexafluoride owned by DOE, such impacts should be considered to be positive (USN 1996a, page 4-10).
Lead or steel could be substituted for depleted uranium for radiation shielding in some cases. If those materials were used for this purpose, the thickness of the substituted material would increase in inverse proportion to the ratio of the density of the substituted material to the density of depleted uranium. If lead or steel were used, the shielding thickness would increase by about 170 percent or 240 percent, respectively, resulting in a much larger container (USN 1996a, page 4-10).

4.1.15.5.5 *Impacts of Waste Generation*

The component materials used in the manufacture of disposal containers and shipping casks would be carbon steel, high-nickel alloy, and stainless steel, with either depleted uranium or lead used for shielding. The manufacture of shielding would generate hazardous or low-level radioactive waste, depending on the material used. Other organic and inorganic chemical wastes generated by the manufacture of disposal containers and shipping casks and the amounts generated have also been identified.

Based on data in USN (1996a, page 4-13), the analysis estimated annual volumes and quantities of waste produced for each packaging scenario per disposal container and shipping cask manufactured at the representative site. The potential for impacts was evaluated in terms of existing and projected waste handling and disposal procedures and regulations. In addition to relevant state regulatory agencies, the Environmental Protection Agency and the Occupational Safety and Health Administration regulate the manufacturing facilities.

Manufacturing to support the different packaging scenarios would produce liquid and solid wastes at the manufacturing locations. To control the volume and toxicity of these wastes, manufacturers would comply with existing regulations. Pollution prevention and reduction practices would be implemented. The analysis evaluated only waste created as a result of the manufacturing process to produce disposal containers and casks from component materials. It did not consider the waste produced in mining, refining, and processing raw materials into component materials for distribution to the manufacturer. The analysis assumed that the component materials, or equivalent component materials produced from the same raw materials, would be available from supplier stock, which would be available without regard to the status of the Yucca Mountain project.

Liquid Waste

The liquid waste produced during manufacturing would consist of used lubricating and cutting oils from machining operations and the cooling of cutting equipment. This material is currently recycled for reuse. Ultrasonic weld testing would generate some unpotable water-containing glycerin. Water used for cooling and washing operations would be treated for release by filtration and ion exchange, which would remove contaminants and permit discharge of the treated water to the sanitary system.

Table 4-51 lists the estimated amounts of liquid waste generated by the shaping, machining, and welding of the vessels required for each packaging scenario. The annual average amount of liquid waste generated would range from 3.4 to 3.8 metric tons (approximately 3.7 to 4.2 tons) per year. The small quantities of waste produced during manufacturing would not exceed the capacities of the existing equipment for waste stream treatment at the manufacturing facility.

Table 4-51. Annual average waste generated (metric tons)[a] at the representative manufacturing location for packaging scenarios.

Waste	Packaging scenario[b] UC	DISP	DPC
Liquid	3.4	3.8	3.4
Solid	0.47	0.52	0.47

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

Solid Waste

Table 4-51 lists the solid waste that manufacturing operations would generate. The annual average amount of solid waste would range from 0.47 to 0.52 metric ton (approximately 0.52 to 0.57 ton) per year. The primary waste constituents would be steel and components of steel including nickel, manganese, molybdenum, chromium, and copper. These chemicals could be added to existing steel product manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium to be incorporated in the components would be delivered to the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, depleted uranium waste would not be generated or recycled at the representative manufacturing site and would not pose a threat to worker health and safety. Lead used for gamma shielding would be cast between stainless-steel components for the shipping casks. Although the production of a substantial quantity of lead waste under any of the packaging scenarios would be unlikely, such waste would be recycled.

4.1.15.5.6 *Environmental Justice*

The purpose of this environmental justice assessment is to determine if disproportionately high and adverse health or environmental impacts associated with the manufacture of disposal containers and shipping casks would affect minority or low-income populations, as outlined in Executive Order 12898 and the President's accompanying cover memorandum. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs and activities on minority and low-income populations. A disproportionately high impact would be an impact (or risk of an impact) in a minority or low-income community that exceeded the corresponding impact on the larger community to a meaningful degree. The analysis discussed below is the analysis used in USN (1996a, Section 4.8), which was adapted to the manufacturing of components for the Yucca Mountain Repository.

The environmental justice assessment considered human health and environmental impacts from the examination of impacts on air quality, waste generation, and health and safety for each scenario. The assessment used demographic data to provide information on the degree to which a scenario would affect minority or low-income populations disproportionately. The evaluation identified as areas of concern those in which disproportionately high and adverse impacts could affect minority or low-income populations.

This evaluation considered the characteristics of the five facilities that manufacture casks or canisters for spent nuclear fuel. For each facility the analysis considered a region defined by an approximately 16-kilometer (10-mile) radius around the site. The percentages of minority and low-income persons comprising the population of the states where the facilities are located were used as a reference.

To explore potential environmental justice concerns, this assessment examined the composition of populations living within approximately 16 kilometers (10 miles) of the five manufacturing facilities to identify the number of minority and low-income individuals in each area. DOE selected this radius because it would capture the most broadly dispersed environmental consequences associated with the manufacturing activities, which would be impacts to air quality. The number of persons in each target group in the defined area was compared to the total population in the area to yield the proportion of minority and low-income persons within approximately 16 kilometers of each facility.

A geographic information system was used to define areas within approximately 16 kilometers (10 miles) of each facility. Linked to 1990 census data, this analytical tool enabled the identification of block groups within 16 kilometers. In cases where the 16-kilometer limit divided block groups, the system calculated the fraction of the total area of each group that was inside the prescribed distance. This fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (USN 1996a, page 4-18). DOE anticipates very small impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (USN 1996a, page 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of disposal containers and shipping casks. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the NWPA requires DOE to maintain the ability to retrieve emplaced waste for at least 50 years after the start of emplacement. Because of this requirement, the EIS includes an analysis of the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 300 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

4.2.1.1 Retrieval Activities

If there were a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Section 2.1.1.2).

On the surface, the retrieved waste packages would be loaded on a vehicle for transport to a Waste Retrieval and Storage Area in Midway Valley, about 3.7 kilometers (2.3 miles) from the North Portal Operations Area, to which DOE would build a rail line or roadway. Figure 4-5 shows the relationship between these areas. The Waste Retrieval and Storage Area would include a Waste Retrieval Transfer Building, support facilities, and a number of concrete storage pads. To retrieve and store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, these facilities would cover about 1 square kilometer (250 acres) (TRW 1999a, Attachment I, page I-8).

DOE based selection of Midway Valley Wash as the site for retrieval activities on the following site selection criteria:

- Proximity to the repository North Portal Operations Area
- Retrieval of the waste in the shortest possible timeframe

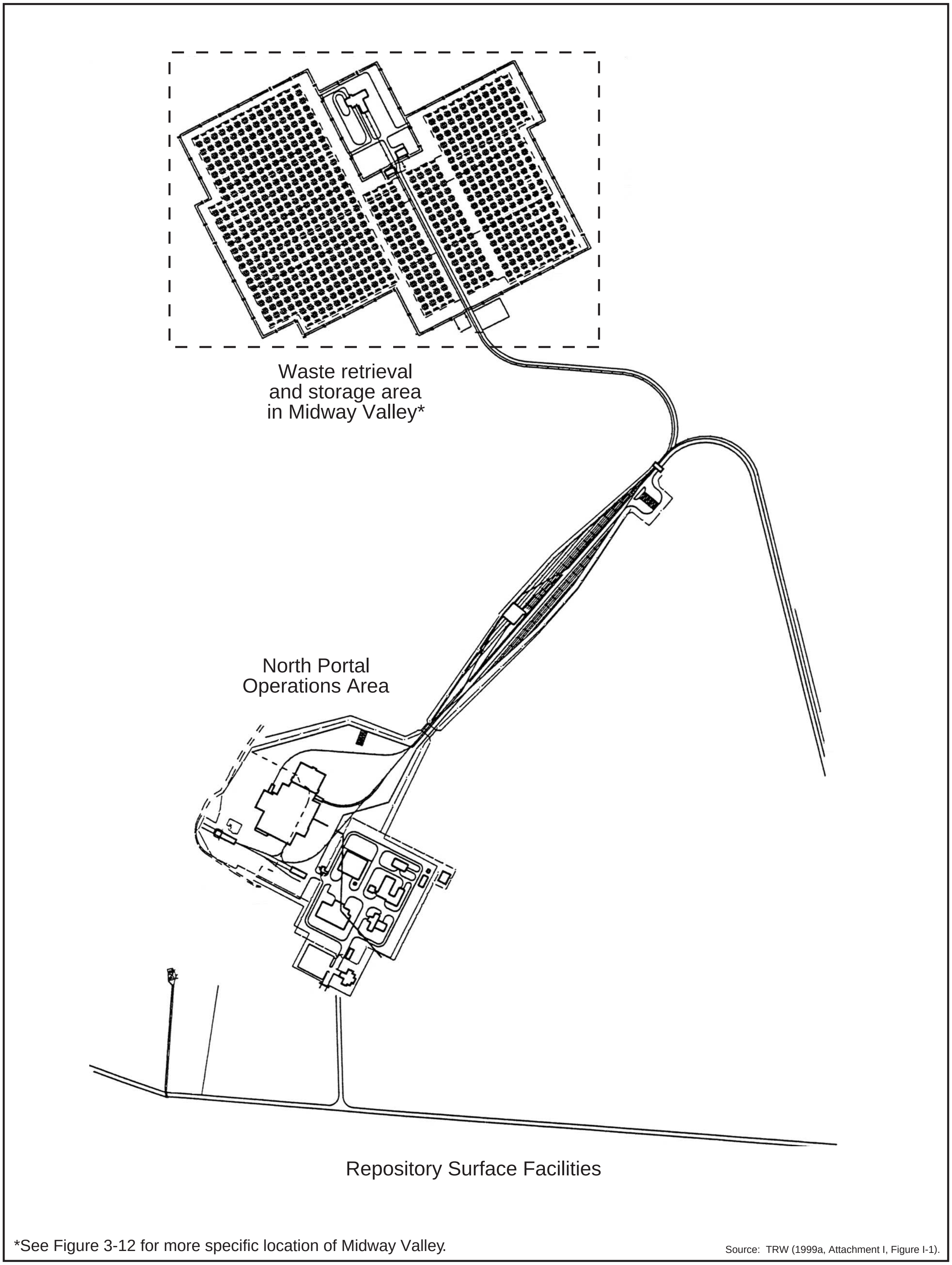


Figure 4-5. Location of the Waste Retrieval and Storage Area in relation to the North Portal Operations Area.

- Adequate space for dry storage of 70,000 MTHM of waste
- No ground displacements due to earthquakes
- Siting outside the probable maximum flood zone
- Minimum costs for construction
- Minimum impacts to the environment

In the Waste Retrieval Transfer Building, the waste packages would be removed and placed in concrete storage modules (one container per module). The concrete module would protect the container and provide shielding. The module and container would then move to a concrete storage pad near the Waste Retrieval Transfer Building, where it would remain awaiting ultimate disposition. Figure 4-6 shows a concrete storage module design concept.

Studies of the strategies and options for retrieval (TRW 1997d, all) indicate it would take about 10 years after a decision to retrieve the emplaced material to plan the operation, procure the necessary equipment, and prepare the Waste Retrieval and Storage Area; about 3 years would involve the construction of facilities and storage areas. To accomplish retrieval would require another 11 years, including additional storage area construction. DOE performed an impact analysis for the retrieval contingency only for the high thermal load scenario. The analysis of impacts for this scenario is sufficient to describe the types and magnitudes of impacts that would occur if DOE implemented the retrieval contingency.

4.2.1.2 Impacts of Retrieval

The following sections present the results of the environmental impact analysis for the retrieval contingency. They consider the construction of the Waste Retrieval and Storage Area, retrieval of the waste packages and their movement to the surface and to the Waste Retrieval and Storage Area, and the loading of the waste packages in concrete storage modules and their placement on concrete storage pads.

4.2.1.2.1 *Impacts to Land Use and Ownership from Retrieval*

Retrieval would cause no land-use impacts during the construction of the Waste Retrieval and Storage Area. DOE would develop a 1-square-kilometer (250-acre) area approximately 3.7 kilometers (2.3 miles) north of the North Portal Operations Area in Midway Valley (see Figure 4-5) on lands already withdrawn from public use.

4.2.1.2.2 *Impacts to Air Quality from Retrieval*

The construction of the Waste Retrieval and Storage Area and the movement of the spent nuclear fuel and high-level radioactive waste to the surface would result in air quality impacts. The analysis considered both radiological and nonradiological impacts. No radiological air quality impacts would occur during the placement of the storage containers in concrete storage modules, assuming the containers remained intact and free from leaks during handling. However, radon-222 would be released from the active ventilation of the subsurface.

Nonradiological Air Quality Impacts. DOE evaluated nonradiological air quality impacts from the retrieval of materials from the repository for (1) the construction of a Waste Retrieval and Storage Area and (2) the retrieval process. Construction and retrieval activities would result in releases of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10}. Retrieval activities would not involve subsurface excavation or result in disturbance of the excavated rock pile, so no releases of cristobalite would occur.

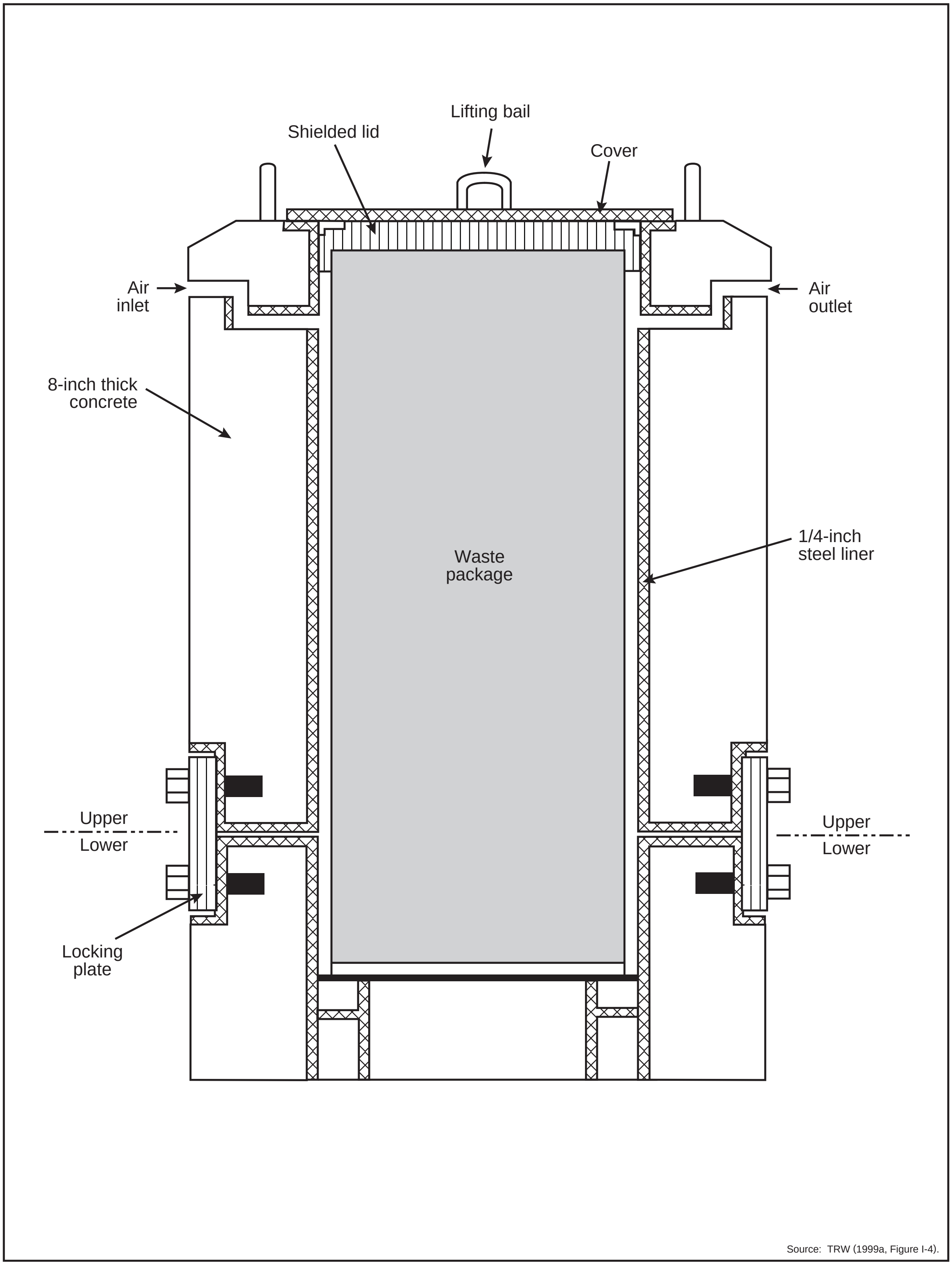


Figure 4-6. Typical concrete storage module design, vertical view.

Construction equipment would release nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} from fuel consumption and PM_{10} in the form of fugitive dust. The analysis did not take credit for the standard construction dust suppression measures that DOE would implement to lower the projected PM_{10} concentrations. Table 4-52 lists calculated concentrations for criteria pollutant impacts to the public maximally exposed individual and compares these concentrations to regulatory limits. The nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} concentrations at the location of the maximally exposed individual would be less than 1 percent of the applicable regulatory limits in all cases.

Table 4-52. Criteria pollutant impacts to public maximally exposed individual from retrieval (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Nitrogen dioxide	Annual	100	0.23	0.23
Sulfur dioxide	Annual	80	0.022	0.028
	24-hour	365	0.18	0.049
	3-hour	1,300	1.4	0.11
Carbon monoxide	8-hour	10,000	2.1	0.020
	1-hour	40,000	13	0.033
Particulates (PM_{10}) ($PM_{2.5}$)	Annual	50 (15)	0.12	0.23
	24-hour	150 (65)	0.83	0.55

a. Appendix G (Section G.1) contains additional information on air quality.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).
d. Sum of the highest concentrations at the accessible site boundary regardless of direction.

Radiological Air Quality Impacts. During retrieval activities subsurface ventilation would continue, resulting in releases of naturally occurring radon-222 and its decay products in the ventilation exhaust. Subsurface ventilation would continue for the duration of retrieval, about 14 years (3 years of initial construction, followed by 11 years of retrieval operations). Table 4-53 lists estimated annual and total doses from 14 years of retrieval activities to maximally exposed individuals and potentially affected populations from radon-222 released from subsurface facilities.

4.2.1.2.3 *Impacts to Hydrological Resources from Retrieval*

4.2.1.2.3.1 Surface Water. The retrieval activity that could have surface-water impacts would be the construction of the Waste Retrieval and Storage Area, which would disturb an area of 1 square kilometer (250 acres).

Potential for Runoff Rate Changes. The total disturbed area would include areas cleared to support construction equipment and materials, facilities, and concrete storage pads. If DOE retrieved all the waste, the storage pad area would account for about 0.43 square kilometer (107 acres) of the disturbed land (TRW 1999a, page I-14). Including the areas covered by facilities, roadways, and queuing areas, most of the land disturbance would result in surface areas that would provide almost no infiltration, so precipitation would result in runoff from the Waste Retrieval and Storage Area. As described in Section 4.1.3.2, if precipitation did not generate runoff from surrounding areas, the runoff from the storage area could travel to otherwise empty drainage channels, but would not go far. If precipitation generated runoff everywhere, there would be little difference in the quantity produced in the storage area; it just would occur earlier in the storm. In addition, a comparison of the 1 square kilometer (250 acres) of disturbed land to the estimated 12 square kilometers (3,000 acres) that make up the Midway Valley Wash drainage area (Bullard 1992, Table 5) indicates that changes in runoff and infiltration rates should have little impact on how the entire drainage area responded to precipitation events.

Table 4-53. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during retrieval operations.[a,b]

Impact	Total	Annual
Dose to public		
Maximally exposed individual[c] (millirem)	5.5	0.43
80-kilometer[d] population[e] (person-rem)	28	2.1
Dose to noninvolved (surface) workers		
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.51	0.039
Yucca Mountain noninvolved worker population (person-rem)	0.72	0.23/0.0067[g]
Nevada Test Site noninvolved worker population[h] (person-rem)	0.046	0.0035

a. Appendix G contains detailed information about the air quality analysis.
b. Construction and retrieval activities would last 13 years.
c. About 20 kilometers (12 miles) south of the repository.
d. 80 kilometers = 50 miles.
e. Approximately 28,000 individuals within 80 kilometers of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker would be at the South Portal Operations Area.
g. First value is dose for construction workforce; second value is dose for retrieval workforce.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Potential for Altering Natural Drainage. The proposed location for the Waste Retrieval and Storage Area does not cross or intercept well-defined drainage channels with the exception of the northwest corner, which could be close to, or possibly overlay, a short stretch of the upper Midway Valley Wash. Other portions of the facility would be in an area where simple overland flow probably would dominate runoff events. Design layouts of the proposed facility call for the construction of an interceptor trench along the upstream (north) side of the area, extending down either side; this would prevent runoff from entering the storage facility and could be an alteration to existing drainage. If flow in this short stretch of the upper Midway Valley Wash was intercepted, it would be diverted around the facility and then back to the existing course. Siting criteria for this proposed facility state that it will be outside the probable maximum flood zone (TRW 1999a, page I-8). Therefore, a probable maximum flood in this small wash will avoid the facility.

Potential for Flooding. The location for the Waste Retrieval and Storage Area would be outside the probable maximum flood zone, and the interceptor trench on the north side of the facility would accommodate the highest quantities of runoff that could reasonably be present. Therefore, there would be no reasonable potential for flooding to affect the storage facility.

4.2.1.2.3.2 Groundwater. The retrieval activities that could have impacts on groundwater would be the construction of the Waste Retrieval and Storage Area and the retrieval of the emplaced material.

Potential for Infiltration Rate Changes. Most of the disturbed land would be covered by facilities, roadways, queuing areas, and storage pads. These facilities would be relatively impermeable to water, and would cause an additional amount of runoff to drainage channels in comparison to natural conditions. This additional runoff could cause a net increase in the amount of water to infiltrate these natural channels. The additional infiltration would move into the unsaturated zone and represent potential recharge to the aquifer, but it would be a minor amount in comparison to natural infiltration.

Impacts to Groundwater Resources. The estimated annual groundwater demand during retrieval would peak at about 110,000 cubic meters (90 acre-feet) a year (TRW 1999a, page I-22; TRW 1999b, page 6-32). No adverse impacts would be likely from this demand, which would be well within historic use rates.

4.2.1.2.4 *Impacts to Biological Resources and Soils*

The retrieval activity that could affect biological resources and soils would be the construction of the Waste Retrieval and Storage Area.

4.2.1.2.4.1 Impacts to Biological Resources from Retrieval

Impacts to Vegetation. The construction of retrieval facilities would disturb vegetation in an area that is presently undisturbed. The predominant land cover types in Midway Valley are blackbrush and Mojave mixed scrub, both of which are extensively distributed regionally and in the State of Nevada.

Impacts to Wildlife. Impacts to wildlife from the retrieval contingency would be similar to those described for the construction and operation of the repository. They would consist of limited habitat loss and the deaths of individuals of some species as a result of construction activities and vehicle traffic, and would be in addition to those associated with repository construction and operation.

Impacts to Special Status Species. Impacts to special status species from the retrieval contingency would be similar, and in addition to, those described for repository construction. They would consist of loss of a small portion of locally available habitat for the desert tortoise and the deaths of individual tortoises due to construction activities and vehicle traffic.

Impacts to Wetlands. No wetlands would be affected by activities associated with retrieval.

4.2.1.2.4.2 Impacts to Soils from Retrieval. Concrete pads, facilities, and roadways at the Waste Retrieval and Storage Area would eventually cover most of the disturbed land, but a sizable portion would remain as disturbed soil.

Soil Loss. Erosion concerns during the construction of the retrieval facilities would be the same as those described for the construction of the repository facilities (see Section 4.1.4.4). The types of soils encountered would be similar to, if not the same as, those encountered during the construction at the North and South Portal Operations Areas. As during other project activities, DOE would use dust suppression measures to reduce the disturbed land's erodibility.

After the construction of the retrieval facilities, much of the area would no longer be exposed to erosion forces because structures would cover the soil. However, the uncovered disturbed areas would be more susceptible to erosion than the surrounding natural areas. This would be the case until the disturbed land had time to reach equilibrium, including the reestablishment of vegetation. Erosion, if it occurred, probably would involve small amounts of soil from small areas. The amount of soil that could move downwind or downgradient should not present unusual concerns.

Recovery. DOE would reclaim disturbed lands when they were no longer needed for retrieval operations.

4.2.1.2.5 *Impacts to Cultural Resources from Retrieval*

The activity that could affect cultural resources would be the construction of the Waste Retrieval and Storage Area. The following sections discuss archaeological and historic resources and Native American interests in relation to retrieval.

Archaeological and Historic Resources. The results of earlier archaeological fieldwork indicate that there are no National Register-eligible archaeological resources on land recommended for the Waste Retrieval and Storage Area or near the proposed rail or road construction. Therefore, construction activities associated with retrieval probably would not result in direct impacts to National Register-eligible archaeological resources. As during repository construction and operation, increased activities and numbers of workers could increase the potential for indirect impacts to archaeological sites near the construction work.

Native American Interests. A Waste Retrieval and Storage Area in Midway Valley would be 500 meters (1,600 feet) west of the Yucca Wash local use area and Alice Hill. As described in AIWS (1998, all), these areas have cultural importance to Native Americans. There could be some direct or indirect impacts to these areas, depending on the specific locations of Native American significance boundaries.

4.2.1.2.6 *Impacts to Socioeconomics from Retrieval*

Waste retrieval activities would increase the repository workforce above that for ongoing monitoring and maintenance activities. A maximum annual employment of about 1,600 workers (TRW 1999a, page I-22; TRW 1999b, page 6-32) would be required during retrieval operations and concurrent storage pad construction. Retrieval would be a short-term operation, lasting about 14 years. The repository workforce would decrease to a small maintenance staff after completion of retrieval. Employment during retrieval would be less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate meaningful changes to the region of influence labor force or economic measures. Regional impacts from retrieval operations would probably be small.

4.2.1.2.7 *Occupational and Public Health and Safety Impacts from Retrieval*

The analysis of health and safety impacts to workers divided the retrieval period into two subperiods, as follows:

- A construction subperiod during which DOE would build (1) the surface facilities necessary to handle retrieved waste packages and enclose them in concrete storage units in preparation for their placement on concrete storage pads, and (2) the concrete storage pads (see Section 4.2.1.1). No radioactive materials would be involved in the construction subperiod, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects this subperiod to last from 2 to 3 years, although construction of the concrete storage pads probably would continue as needed during most of the operations subperiod. No health and safety impacts to the public would be likely during the initial 2- to 3-year construction subperiod.

- An operations subperiod during which DOE would retrieve the waste packages and move them to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The waste package would be enclosed in a concrete storage unit that, with the waste package inside, would be placed on the concrete storage pad. This subperiod would last about 11 years. The analysis estimated the health and safety impacts from both industrial hazards and from radiological hazards for the operations subperiod for both surface and subsurface workers. Radiological impacts to the public could occur during the operations subperiod when radon-222 and its decay products would be released to the environment in the exhaust stream from the subsurface ventilation system.

The methods used to estimate health and safety impacts to workers and the public were the same as those used to estimate such impacts for the Proposed Action (see Appendix F, Section F.2.1). Additional information pertinent to health and safety impact analysis for retrieval is contained in Appendix F, Section F.4. Section F.4.3 contains detailed information on health and safety impacts which supports the impact summary tables in this section.

Construction Subperiod

As noted above, the only health and safety impacts for this subperiod would be those from industrial hazards during normal workplace activities.
Table 4-54 summarizes these impacts. Projected fatality would be about 0.05 and projected lost workday cases would be about 40.

Table 4-54. Industrial hazards health and safety impacts for surface facility workers for retrieval construction subperiod.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	69
Lost workdays	33
Fatalities	0.03
Noninvolved workers	
Total recordable cases	14
Lost workdays	7
Fatalities	0.01
All workers (totals)	
Total recordable cases	83
Lost workdays	40
Fatalities	0.04

a. Sources: Impact rates from Table F-46 and full-time equivalent work years from Table F-45.

Operations Subperiod

Industrial Hazard Impacts to Workers.
Table 4-55 lists estimated impacts from industrial hazards for both surface and subsurface workers for the operations subperiod. Because the impact estimates would not vary greatly with the thermal load scenario, the table lists only one set of impact values (for the low thermal load). Impacts would be small and about twice those for the construction subperiod.

Table 4-55. Industrial hazards health and safety impacts for retrieval operations subperiod.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	35
Lost workday cases	15
Fatalities	0.03
Noninvolved workers	
Total recordable cases	35
Lost workday cases	17
Fatalities	0.04
All workers (totals)	
Total recordable cases	70
Lost workday cases	32
Fatalities	0.07

a. Sources: Tables F-48 and F-49.

Radiological Health Impacts to Workers.
Table 4-56 lists radiological health impacts for both surface and subsurface workers for the retrieval contingency as well as the total radiological impact. Appendix F contains additional details on the radiological exposure components for the subsurface worker exposure. Impacts would be small, with the latent cancer fatality likelihood for the maximally exposed individual being about 0.003. The calculated latent cancer fatality incidence to workers for retrieval would be 0.19.

Radiological Health Impacts to the Public. See Table 4-53 for estimated radiological impacts to the public from releases of radon-222 and its decay products through the subsurface ventilation system exhaust.

Table 4-57 lists estimated radiological health impacts to the public over the operations subperiod. The calculated radiological health impacts to members of the public from a retrieval operation would be small. The calculated likelihood of a latent cancer fatality for the maximally exposed individual would be about 2.8×10^{-6}. The calculated latent cancer fatality incidence would be about 0.014.

Table 4-56. Radiological health impacts from retrieval operations.[a,b]

Worker group and impact category	Surface facility workers	Subsurface facility workers	Total/High
Involved workers			
Maximally exposed individual dose[c]	4,400	6,950	6,950[d]
Latent cancer fatality probability	0.002	0.003	0.003[d]
Collective dose (person-rem)	75	380	455
Latent cancer fatality incidence	0.03	0.15	0.18
Noninvolved workers			
Maximally exposed individual dose	280	1,290	1,370[d]
Latent cancer fatality probability	0.0001	0.0005	0.0005[d]
Collective dose (person-rem)	6	22	28
Latent cancer fatality incidence	0.002	0.009	0.01
All workers (totals)[e]			
Collective dose (person-rem)	81	400	480
Latent cancer fatality incidence	0.03	0.16	0.19

a. Sources: Appendix F, Tables F-51 and F-52.
b. There would be no radiological health impacts to the public during the construction subperiod.
c. For 11-year period of operation (millirem).
d. Values are not totals, but the largest of the compounds.
e. Totals might differ from sums of values due to rounding.

Table 4-57. Radiological health impacts to the public for retrieval operations period.[a,b]

Worker group and impact category	Impact
Individual	
Maximally exposed individual (millirem)	5.5
Latent cancer fatality probability	2.8×10^{-6}
Population	
Collective dose (person-rem)	28
Latent cancer fatality incidence	0.014

a. Source: Table 4-49.
b. There would be no radiological health impacts to the public during the construction subperiod.

Radiological Health Impacts to the Public. The potential for exposure of members of the public to radiological materials released as a result of retrieval operations would exist only during the operations subperiod. These impacts are summarized in Table 4-57. The predicted incidence of latent cancer fatality would be about 0.1.

4.2.1.2.8 *Impacts from Accidents During Retrieval*

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened. The handling accident scenario applicable for these operations would be bounded by the transporter

Summary of Impacts

Industrial Health and Safety Impacts to Workers for Retrieval. Table 4-58 summarizes the industrial health and safety impacts to workers from the retrieval construction and operations subperiods. Estimated fatalities would be low, about 0.1, with about 72 lost workday cases.

Radiological Impacts to Workers. Radiological impacts to workers from retrieval would occur primarily during the operations subperiod, as summarized in Table 4-56.

Table 4-58. Overall industrial hazards health and safety impacts for retrieval.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	100
Lost workday cases	48
Fatalities	0.07
Noninvolved workers	
Total recordable cases	48
Lost workday cases	24
Fatalities	0.04
All workers (totals)	
Total recordable cases	150
Lost workday cases	72
Fatalities	0.11

a. Sources: Tables 4-58 and 4-59

runaway accident scenario evaluated in Section 4.1.8. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval and Storage Area (DOE 1997m, all). This area would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a vertical concrete storage unit, and moved to a concrete storage pad.

Because the retrieval operations would be essentially the same as the emplacement operations (in reverse), the accident scenarios involving the waste package during operations would bound the retrieval operation. The bounding accident scenario during emplacement would be a transporter runaway and derailment accident in a main drift (see Appendix H, Section H.2.1.4). For above-ground storage accidents, the accident analysis for the continued storage analysis would apply. Recent analyses have found that the only credible accident with meaningful consequences would be an aircraft crash into one of the above-ground storage facilities. However, the aircraft penetration potential would not be sufficient to breach the thickness of the waste package (Davis 1998, all).

The analysis assumed that above-ground storage following retrieval would be licensed in compliance with Nuclear Regulatory Commission requirements (10 CFR Part 72). These requirements specify that storage modules must be able to withstand credible accident-initiating events.

4.2.1.2.9 *Aesthetic Impacts from Retrieval*

Retrieval activities would not be likely to produce adverse impacts on the visual quality of the landscape surrounding Yucca Mountain. Retrieval would essentially be the reverse of emplacement and would use the same types of equipment. Impacts from emplacement would be small. The only difference from the emplacement activities would be the construction of a Waste Retrieval and Storage Area in Midway Valley north of the North Portal Operations Area with a connecting transportation corridor. These activities would occur in the repository area and in Class C scenic quality lands away from the public view and, therefore, would have no impact on the existing visual character of the landscape.

4.2.1.2.10 *Noise Impacts from Retrieval*

The analysis in Section 4.1.9 shows that there would be no appreciable noise impacts for the construction, operation and monitoring, and closure phases of repository operations. Noise impacts associated with retrieval would be less than those associated with repository operations because of the reduced scope of activities and the smaller number of workers required. Worker traffic noise levels would also be less because fewer workers would commute to the site. Thus, noise impacts from retrieval operations would be small.

4.2.1.2.11 *Impacts to Utilities, Energy, Materials, and Site Services from Retrieval*

The following sections discuss utility, energy, materials, and site service impacts.

Utilities and Energy. The estimated electric power demand for retrieval would be less than 10 megawatts. This demand would be well within the capacity that would be available at the repository.

The fossil-fuel use estimated for retrieval activities would approach 25 million liters (6.6 million gallons). This consumption level is less than 0.1 percent of the annual consumption in the State of Nevada.

Materials. For the Waste Retrieval and Storage Area, DOE would build a concrete pad and retrieval support facilities. Construction would require about 540,000 cubic meters (410,000 cubic yards) of concrete and 42,000 metric tons (46,000 tons) of steel, which would not affect the regional supply capacity. About 10,000 concrete storage modules would be required. The concrete would be obtained from offsite sources or the onsite batch plant would be used. The storage modules would be relatively simple concrete vessels with a 0.64-centimeter (0.25-inch) steel liner. About 110,000 cubic meters (140,000 cubic yards) of concrete would be required to build 10,000 modules, which probably would be manufactured commercially. Material usage impacts would be small. The impacts of shipping about 10,000 concrete storage modules to the site would be comparable to those for shipping about 10,000 storage containers to the site (see Section 6.2.5).

Site Services. The onsite emergency response capability and the security, medical, and fire protection units that would support operations would be available to support retrieval, so no additional impacts would be likely.

Table 4-59 summarizes impacts to utilities, energy, and materials.

Table 4-59. Utilities, energy, and materials for retrieval.[a,b,c]

	Electric		Fossil fuel	Construction materials	
Location	Peak (MW)[d,e]	Use (1,000 MWh)[f]	Liquid fuels (million liters)[g]	Concrete (1,000 cubic meters)[h]	Steel (1,000 metric tons)[i]
Surface	1.2	82	20	540	42
Subsurface	7.7	270 - 520	2.5	0	0
Totals	**8.9**	**350 - 600**	**22.5**	**540**	**42**

a. Sources: TRW (1999a, pages I-22 to I-24); TRW (1999b, page 6-35).
b. All entries except peak electric power are cumulative totals for the entire period.
c. Approximate retrieval period would be 11 years.
d. Peak electric power is the peak demand that would occur during the period.
e. MW = megawatts.
f. MWh = megawatt-hours.
g. To convert liters to gallons, multiply by 0.26418.
h. To convert cubic meters to cubic yards, multiply by 1.3079.
i. To convert metric tons to tons, multiply by 1.1023.

4.2.1.2.12 *Impacts to Waste Management from Retrieval*

The construction of the Waste Retrieval and Storage Area would generate an estimated 12,000 cubic meters (420,000 cubic feet) of construction debris, 2,400 cubic meters (85,000 cubic feet) of sanitary and industrial solid waste, and 450 cubic meters (16,000 cubic feet) of hazardous waste (TRW 1999a, page I-22). Based on operations generation rates (TRW 1999a, page 76; TRW 1999b, page 6-34), the retrieval of the storage containers would generate an estimated 5,100 cubic meters (180,000 cubic feet) of sanitary and industrial solid waste. Throughout the construction of the retrieval facilities and retrieval operations, the workforce would generate sanitary sewage. After the spent nuclear fuel and high-level radioactive waste were placed in the concrete storage modules and on the concrete storage pads, waste generation would continue due to the presence of a workforce. Surveillance and monitoring activities would generate sanitary and industrial solid and low-level radioactive waste.

Construction debris and sanitary and industrial solid waste would be disposed of at onsite facilities or at the Nevada Test Site. Sanitary sewage would be disposed of at onsite facilities. Low-level radioactive waste would be disposed of at the Nevada Test Site or another government or commercial facility in accordance with applicable Federal and state requirements. Hazardous waste would be shipped off the site for treatment and disposal at a permitted commercial facility. The National Capacity Assessment

Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) shows that the available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come. Therefore, hazardous waste possibly generated during retrieval activities would have a very small impact on the capacity for treatment and disposal at commercial facilities.

4.2.1.2.13 *Impacts to Environmental Justice from Retrieval*

Workers at the Yucca Mountain site would be representative of the population mix in the surrounding areas of Nevada. Hence, there would be no disproportionate impacts to minority or low-income populations in the Yucca Mountain region or to the workers during retrieval operations. In addition, because disproportionate impacts to minority or low-income populations from repository construction and operation would be unlikely, none would be likely from retrieval.

4.2.2 IMPACTS FROM RECEIPT PRIOR TO THE START OF EMPLACEMENT

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and that emplacement would occur over a 24-year period ending in 2033 (70,000 MTHM at approximately 3,000 MTHM per year). The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 10,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. However, because the amounts of these materials would be smaller than those analyzed for the retrieval contingency, the overall impacts from the Waste Staging Facility would be smaller than those described in Section 4.2.1.